02.2019

VALLEY OF THE BOOM | TV SERIES AIRS SUNDAYS AT 9/8C ON NATIONAL GEOGRAPHIC

NATIONAL GEOGRAPHIC

THE ULTIMATE CLIMB

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Options shown. 1. 2019 UX vs. 2018/2019 competitors. Information from manufacturers' websites as of 9/17/2018. 2. Apple CarPlay is a trademark of Apple Inc. All rights reserved. Always drive safely and obey traffic laws. Apps, prices and services vary by phone carrier and are subject to change at any time without notice. Subject to smartphone connectivity and capability. Data charges may apply. Apple CarPlay® functionality requires a compatible iPhone® tethered with an approved data cable into the USB media port. 3. iPhone is a registered trademark of Apple Inc. All rights reserved. 4. 2019 Lexus UX 200 EPA 29/city, 37/hwy, 33/comb MPG estimates. Actual mileage will vary. 5. UX AWD system operates at speeds up to 43 mph. ©2018 Lexus

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This docudrama about the internet's early days airs Sunday nights through January 27 at 9/8c, on National Geographic.

HOW CAN BIG DATA MAKE A DIFFERENCE?



"Big data" lives up to its name: We produce 2.5 quintillion bytes of data every day through the staggering array of digital connections that link people, objects, and devices. Every email, text, post, online search, app interaction, card transaction, and doctor's visit contribute to the three V's that define big data: volume, velocity, and variety of information, in greater amounts than ever before (it's estimated that 90 percent of all data in existence was generated in the last two years). But to be useful, another V is needed: value. Extracting value takes powerful computers, complex algorithms, and extraordinary brainpower, a combination that saw "data scientist" hailed as the world's sexiest job. But is big data really making a difference?



Many believe it is. Retailers are using it to enhance our shopping experience, from predicting popular products and engaging interest to ensuring availability and competitive pricing. In the United States, Macy's department store credits big data with improving their customer interactions and helping to boost sales by 10 percent.

> **BANKS ARE ALSO INVESTING, WITH OVER $20 BILLION SPENT ON DATA ANALYSIS IN 2016.**

One area to benefit is customer service, where valuable information collected is supporting speedier decisions on loans and credit while providing better protection against theft, fraud, and even overspending.

Health care is also seeing a marked difference, where data collection is helping to reduce preventable deaths, improve quality of life, predict epidemics, and cure diseases.

It's even used in cancer research. A cancer patient can generate terabytes of biomedical data, and locked inside could be the key to a cure. Big data searches for patterns to predict how cancers will behave and recently led to the breakthrough discovery that a commonly used antidepressant has the potential to help find a cure for lung cancer.

Big data is still just getting started, but it already impacts almost every area of our lives—mostly attempts to make them better. By 2020, there will be 200 billion, according to Intel, connected devices, and we're predicted to generate 1.7 megabytes of data per person, per second. If computational power and data scientists can keep pace with such growth, the potential for big data to make an even bigger difference is huge.



TELEVISION

New Episodes of *Life Below Zero*

Intrepid residents of remote spots in Alaska pit their survival skills against carnivorous wild animals, white-out storms, and other perils in the Emmy Award–winning series. New episodes air Tuesdays at 9/8c on National Geographic.

NAT GEO WILD

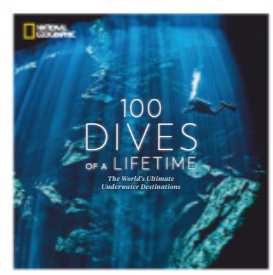
Night Stalks Animals in *Dead by Dawn*

Mother Nature shows her sadistic side in TV's first nature horror series, *Dead by Dawn*. Inspired by cult classic horror films, the series tells stories of night predators and prey, from Indonesia to the United States. It airs Fridays at 9/8c from January 13 through February 17 on Nat Geo WILD.

BOOKS

Explore the Planet's 'Ultimate Underwater Destinations'

For scuba lovers or those who aspire to be, *100 Dives of a Lifetime* is a guide to stunning dive locations. Available February 26 where books are sold and at *shopng.com/books*.



NAT GEO BOOKS



100 Parks, 5,000 Ideas Showcases the Best of U.S. and Canadian Parks

National Geographic pairs stunning photography with expert travel advice about 100 national, state, and city parks in this sequel to the best-selling *50 States, 5,000 Ideas*. Consult the book's top-10 lists to find the best destinations for river trips, monuments, panoramic views, beaches, and more. Available February 12 where books are sold and at *shopng.com/books*.

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PHOTO: KEITH LADZINSKI

THE TECH RECKONING

Technology's Peaks and Valleys

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **LAURA MORTON**



Because of the high cost of housing in Silicon Valley, many people turn to living in RVs—here, lining El Camino Real in Palo Alto next to Stanford University's campus.

Visit the Silicon Valley of the 1990s in the series *Valley of the Boom,* airing Sunday nights at 9/8c through January 27, on National Geographic. Check local listings.

I WAS AN EDITOR at the San Jose *Mercury News* in 1989 when, at 5:04 p.m. on October 17, tectonic plates shifted under the Santa Cruz Mountains in Northern California and the ground started rumbling. When the magnitude 6.9 earthquake finally stopped, scores of people had lost their lives; parts of the Bay Area would not fully recover for a decade.

At that same time, other forces were shaking Silicon Valley, though many of us didn't realize it. The information industry was being radically transformed by technologies coming to life all around us—an upheaval that continues today, with enormous implications.

Technology reporter Michelle Quinn has been there to cover it all, from the early days of the dot-com bubble until now, when digital devices touch every aspect of our existence, for good or ill. Thanks to the technology developed in Silicon Valley, our lives have become exponentially richer and easier. Yet we also are haunted by security breaches, unauthorized uses of personal data, the difficulty in discerning the truth amid the blizzard of information at our fingertips.

In this month's magazine, Quinn writes of the billions "made on start-ups I dismissed as toys, solving problems I didn't know people had." Such success is great for an invention's creators and often for users. But it spawns economic inequality that has pushed out people who can't afford to live where median home prices top a million dollars. "You could argue that every great thing about the digital era is going to have an unintended consequence or a trade-off," says Quinn. "You get to talk to people around the world—but the trade-off is, then your information's out there. So how do you mitigate the harm?"

Along with Silicon Valley, we look at what fuels these tech toys: lithium. We sent writer Robert Draper and photographer Cédric Gerbehaye to Bolivia, where the world's largest salt flat covers one of the biggest deposits of lithium, nearly a sixth of the planet's total.

"What gold meant to earlier eras, and petroleum to the previous century, lithium may eclipse in the coming years," Draper writes. It's "an essential component for the batteries in computers, cell phones, and other electronic devices," as well as in electric cars.

The mining of lithium has the potential to lift Bolivia out of poverty. But it also raises urgent questions about whether the benefits of this "white gold" will accrue to corporations more than to Bolivians and whether mining will mar the environment and affect tourism to the salt flat that lies above. Like the story of Silicon Valley, the tale of Bolivia's lithium is a complicated one—with, as Quinn might say, inevitable trade-offs. ▯

PROOF

PHOTOGRAPHS BY **ALICE MANN**

NATIONAL GEOGRAPHIC

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE



SOUTH AFRICA'S MAJORETTES

Young women in uniform grow in confidence and pride.

VOL. 235 NO. 2



There are no days off for "drummies." On "a national holiday, the Fairmont High School Drum Majorettes gather to practice elaborate routines.









Schools typically provide uniforms, though parents pay a fee. The color of a busby hat signifies which routine the girls will perform or in some cases designates rank.



Keisha Ncube, nine, has been a drum majorette for three years. Girls who join at a young age often stay into their teens, using their experience to guide other girls through intense practices and competitions.



While many drummies are from low-income families, the girls on the highly ranked Fairmont High School team represent a wide range of backgrounds.



THE BACKSTORY

SOUTH AFRICA'S TRADITION OF DRUM MAJORETTES IS PART SPORT, PART DANCE, AND ALL CONSUMING.

KNOWN AS DRUMMIES, drum majorettes began appearing in Cape Town street parades in the 1970s. Today they're part of competitive clubs, often in schools. Though open to everyone, these teams tend to attract girls from marginalized communities. The long hours of repetitive practice are appreciated as a way to build confidence, pride, and a positive work ethic.

Girls as young as five and women into their 20s are drawn to the mix of cheerleading and marching band. They rehearse elaborate routines for regional competitions, where their appearance and precision earn them accolades. But they're also judged on leadership and character.

South African photographer Alice Mann started taking pictures of drummies in 2016. She was attracted by their energy, femininity, and empowerment. Mann watched the girls practice and perform. She noticed how a girl's body language changed the moment she put on her uniform. And she saw the hopes of parents—particularly the "drummy mummies"—who support the clubs by raising money and repairing uniforms.

Enthusiasm and energy are renewable resources. But the activity has lately been in decline, a consequence of struggling schools and, perhaps, more opportunities for young girls to connect, especially online.

Still, there are plenty of drummies in Cape Town who come for all-day competitions and who see the long-term value of such a demanding activity. "To be a drummy is very affirming," says Mann. "It teaches them things they can apply throughout their lives." —DANIEL STONE



Girls who become drum majorettes early tend to form a support structure of strong friendships.

THE DISCOVERIES OF TODAY THAT WILL DEFINE THE WORLD OF TOMORROW

NATIONAL GEOGRAPHIC | VOL. 235 NO. 2

How Ketchup Made Food Safer

IF BACTERIA IN KETCHUP DIDN'T SICKEN YOU, THE PRESERVATIVES MIGHT—UNTIL HENRY J. HEINZ CLEANED UP THE CONDIMENT.

BY **DEBORAH BLUM**

KETCHUP—THAT CHEERFUL RED SAUCE sold in handy glass bottles—first came on the American market in the 19th century. But its ingredients were shockingly different than they are today.

Food advocates complained that the sauce was frequently made from tomato scraps thickened with ground pumpkin rinds, apple pomace (the skin, pulp, seeds, and stems left after the fruit was pressed for juice), or cornstarch, and dyed a deceptive red. One French cookbook author described the ketchup sold in markets as "filthy, decomposed and putrid."

By the late 19th century, it would become less putrid, as manufacturers added chemical preservatives to slow decomposition in the bottle. But the real change—the invention of modern ketchup—occurred in the 20th century, and it's a story of both politics and personality. It begins with an unlikely alliance between one of the country's richest food manufacturers, Henry J. Heinz, and an underpaid



ILLUSTRATION: JOHANNA GOODMAN (IMAGES OF HENRY HEINZ, HIS COMPANY'S PRODUCTS, AND A HEINZ FACTORY)



A Persistent Preservative

The preservative sodium benzoate, which Heinz removed from its ketchup at the turn of the 20th century, was enormously controversial at the time. Synthesized by German chemists in 1860, it was one of the additives tested for safety by federal chemist Harvey Washington Wiley, and it was, he insisted, a serious health risk.

His critics claimed that Wiley was exaggerating the dangers. The preservative was based in nature, they said: a salt of a naturally occurring compound, benzoic acid, found in a wide variety of plants, from tobacco to cranberries. Food manufacturers took up its use after learning it had antimicrobial properties.

After passage of the 1906 Pure Food and Drug Act, Wiley urged the government to remove it from the food supply, but other research suggested that at a tiny amount—one-tenth of one percent—it did not pose a great risk. The government accepted those counter findings, and today the preservative is used in products ranging from salad dressing to bottled lemon juice. But it's rarely found in ketchup. —DB

IN THE LATE 1800s, U.S. FOOD SAFETY TESTERS FOUND 'A DISMAYINGLY RECKLESS USE OF UNTESTED PRESERVATIVES.'

federal chemist. The two men bonded over a mutual belief that unsafe and untrustworthy food was a growing national problem.

Harvey Washington Wiley's position on the matter surprised no one. As chief of the U.S. Department of Agriculture's chemistry bureau, Wiley had been pushing for food safety standards since the 1880s. At that time, his tiny department was the only federal division responsible for the country's food quality. His chemists had exposed both widespread fraud—from gypsum in flour to brick dust in cinnamon—and a dismayingly reckless use of untested preservatives, ranging from formaldehyde to borax.

Heinz's stance was a shock, especially to his fellow industrialists. He refused to fall in line with other U.S. corporations, which were mostly moving to block any effort to establish food and drink standards. And to understand that, we need to take a look at the man himself as well as the successful businessman.

HE WAS BORN IN 1844 in Pittsburgh, the son of German immigrant parents. His parents, John and Anna Margaretha, were devout Lutherans; their children—Henry was the oldest of eight—were educated at a Lutheran school. Their mother insisted they live by Christian principles: "Do all the good you can. Do not live for yourself," was one of her favorite sayings. It was also expected that the children would work hard and make a good living. That went without saying.

As a child Henry sold extra vegetables from the family's kitchen garden to neighbors; by age 10 he had his own garden and carried produce by wagon to local grocers. By the time he was a teen, he was delivering produce to the grocers by horse cart and also selling prepared horseradish in small glass jars. Many commercial varieties were sold then in colored glass—sometimes for decorative purposes, sometimes because it obscured the contents. Young Heinz deliberately used clear glass so that customers could see the horseradish inside. By 1888, at age 44, he had his own food manufacturing business, the H.J. Heinz Company, and from there he never looked back.

Heinz's company made some 60 products in 1896—and that would rise to 200 by the turn of the century. The company still offered horseradish but also pickles, ketchup, vinegars, chili sauces, tomato sauce, mincemeat, fruit butters, baked beans, preserved cherries, mustard dressings, currant jelly, pineapple preserves, an assortment of mustards, canned pastas. Heinz was a master promoter—the company used everything from lighted billboards to painted wagons to displays at World Fairs to advertise its products.

But Heinz also believed that for promotion to succeed, the product itself had to be good, the manufacturer trustworthy. He allowed public tours of his Pittsburgh factory so that people could admire its cleanliness and well-treated workers. He built greenhouses to experiment with the best varieties of fruits and vegetables. He continued to use clear glass, rather than colored, for his products. For his ketchup, he created one with an eight-sided base so customers could study the sauce from many angles.

And it was ketchup itself that would inspire him to go even further.

AS THE STORY GOES, ketchup began as an Asian sauce made of fermented fish. Some say it was invented in China in the sixth century and named *ke-tsiap.* Others say it came from Vietnam, and still others argue for a different beginning in the West Indies.

In other words, we don't really know. What we do know is that the early tomato-based ketchups on U.S. shelves were rich environments for bacteria, mold, and other microbes—until bottlers began dosing the sauce with chemical preservatives.

Heinz, like other manufacturers, used chemical preservatives in his ketchup until the late 1800s. His original recipe, based on his mother's, used salicylic acid derived from tree bark (some say slippery elm, others willow). Later he shifted to the newly popular preservative sodium benzoate, industrially made, cheap, tasteless, and effective. But as Wiley and other scientists began raising questions about the safety of the new preservatives, Heinz paid attention.

More than that, he set his company on a quest to be a leader in preservative-free products. He asked the company's general manager—his cousin, Sebastian Mueller—to begin developing condiments that would need no chemical additives. Mueller warned him these would be costly to develop. Heinz had always offered a money-back guarantee, and the general manager also feared that a preservative-free ketchup would spoil easily, leading to costly returns.

But Heinz was not deterred. And Mueller became increasingly committed to the idea. A believer in scientific principles, he began to experiment with recipes for a homemade ketchup that would have a longer shelf life. He wanted a bacteria-killing acid concentration in the formula and so sought the right balance of vinegar and pectic acid, the latter occurring naturally in tomatoes. To get the acid levels right,

THE EARLY TOMATO-BASED KETCHUPS ON U.S. SHELVES WERE RICH ENVIRONMENTS FOR BACTERIA, MOLD, AND OTHER MICROBES.

Mueller discovered, he needed both high-quality tomatoes and high pulp content. Ketchups had traditionally been thin sauces of mixed content. To create its preservative-free ketchup, the company switched to a thicker, tomato-rich version—the foundation for the condiments of today.

This was not all altruism. The risks of preservatives were gaining wider public attention, thanks in part to the work of Wiley, who had begun testing them on human volunteers in 1902. The studies—nicknamed "the Poison Squad"—and the test subjects' resulting ailments were front-page news across the country. Heinz was beginning to suspect that consumer distrust of the food supply would be far more expensive to manufacturers like him than the cost of improving the food itself.

His company started rolling out advertisements, publicly touting the purity of its products. And privately, Heinz made sure that major politicians, including President Theodore Roosevelt, were aware of his concerns. When food safety advocates met with Roosevelt in 1905 to urge legislation, Heinz representatives joined them.

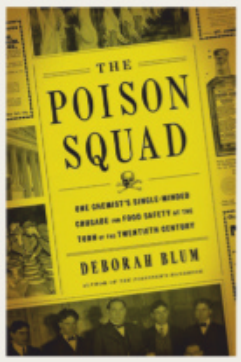
The following year another food scandal roiled the industry. This was driven by the publication of Upton Sinclair's novel *The Jungle,* packed with horrifying details about meat production in Chicago. By then the president, Congress, even a majority of manufacturers realized protection legislation was a necessity. In June 1906 the first two pieces of major consumer protection legislation in the United States—the Meat Inspection Act and the Pure Food and Drug Act—became law, laying the foundation for federal safety regulations.

And H.J. Heinz's new, preservative-free ketchup was ready to go. As the company's advertising campaign proclaimed, it was "recognized as the standard by Government pure food authorities." It was also the new model for American ketchup—a thick mixture of politics, personality, a 20th-century acceptance that food safety matters, and of course, tomatoes. ▯

'Poison' Penned

Pulitzer Prize–winning journalist Deborah Blum is director of the Knight Science Journalism Program at MIT. Her books include *The Monkey Wars* and her latest, *The Poison Squad.*

Essay drawn from *The Poison Squad* by Deborah Blum, published by Penguin Press, an imprint of Penguin Publishing Group, a division of Penguin Random House, LLC. Copyright © 2018 by Deborah Blum.



THE BEST TOOL FOR THE JOB

PHOTOGRAPH BY
EMANUELE BIGGI

The mating moves of male stag beetles (genus *Odontolabis*) may be influenced by their equipment, researchers suggest. Some have hefty mandibles, as seen here, and can muscle out rivals for mates. Smaller ones with lesser mandibles may resort to sneak attacks on females.
–PATRICIA EDMONDS





You can't wish the flu away.

Indication
XOFLUZA is a prescription medicine used to treat the flu (influenza) in people 12 years of age and older who have had flu symptoms for no more than 48 hours.

It is not known if XOFLUZA is safe and effective in children younger than 12 years of age or weighing less than 88 pounds (40 kg).

Important Safety Information
Do not take XOFLUZA if you are allergic to baloxavir marboxil or any of the ingredients in XOFLUZA.

Before you take XOFLUZA, tell your healthcare provider about all of your medical conditions, including if you:
- are pregnant or plan to become pregnant. It is not known if XOFLUZA can harm your unborn baby
- are breastfeeding or plan to breastfeed. It is not known if XOFLUZA passes into your breast milk

Tell your healthcare provider about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Brief Summary
XOFLUZA™ (zoh-FLEW-zuh)
(baloxavir marboxil) tablets

What is XOFLUZA?
XOFLUZA is a prescription medicine used to treat the flu (influenza) in people 12 years of age and older who have had flu symptoms for no more than 48 hours.

It is not known if XOFLUZA is safe and effective in children less than 12 years of age or weighing less than 88 pounds (40 kg).

Do not take XOFLUZA if you are allergic to baloxavir marboxil or any of the ingredients in XOFLUZA. See the end of this leaflet for a complete list of ingredients in XOFLUZA.

Before you take XOFLUZA, tell your healthcare provider about all of your medical conditions, including if you:
- are pregnant or plan to become pregnant. It is not known if XOFLUZA can harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if XOFLUZA passes into your breast milk.

Tell your healthcare provider about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Talk to your healthcare provider before you receive a live flu vaccine after taking XOFLUZA.

How should I take XOFLUZA?
- Take XOFLUZA exactly as your healthcare provider tells you to.
- Your healthcare provider will prescribe a single dose of XOFLUZA (which may be more than one tablet).
- Take XOFLUZA with or without food.
- Do not take XOFLUZA with dairy products, calcium-fortified beverages, laxatives, antacids or oral supplements containing iron, zinc, selenium, calcium or magnesium.
- If you take too much XOFLUZA, go to the nearest emergency room right away.

xofluza™
(baloxavir marboxil) tablets 20mg 40mg

But now you can attack it with new, one-dose XOFLUZA.

The flu is serious. And it needs to be treated that way. Over-the-counter remedies treat flu symptoms. One-dose XOFLUZA attacks the flu virus at its source and helps you feel better in just over two days.*

Why wait? Prescription XOFLUZA is most effective within the first 48 hours of symptoms. Talk to your doctor as soon as you feel signs of the flu.

Visit XOFLUZA.com/save to see if you're eligible to pay as little as $30 for your XOFLUZA prescription.**

*On average patients recovered from flu symptoms in 2.3 days (54 hours versus 80 hours with placebo).

**Terms and conditions apply (see XOFLUZA.com/save for full list of terms and conditions).

Talk to your healthcare provider before you receive a live flu vaccine after taking XOFLUZA.

Take XOFLUZA with or without food. Do not take XOFLUZA with dairy products, calcium-fortified beverages, laxatives, antacids, or oral supplements containing iron, zinc, selenium, calcium, or magnesium.

The most common side effects are diarrhea, bronchitis, nausea, common cold symptoms (nasopharyngitis), and headache.

XOFLUZA is not effective in treating infections other than influenza. Other kinds of infections can have symptoms like those of the flu or occur along with flu and may need different kinds of treatment.
Tell your healthcare provider if you feel worse or develop new symptoms during or after treatment with XOFLUZA or if your flu symptoms do not start to get better.

Please see brief summary on this page.

You are encouraged to report side effects to Genentech by calling 1-888-835-2555 or to the FDA by visiting www.fda.gov/medwatch or calling 1-800-FDA-1088.

What are the possible side effects of XOFLUZA?
The most common side effects of XOFLUZA in adults and adolescents include:

- diarrhea
- bronchitis
- common cold symptoms (nasopharyngitis)
- headache
- nausea

XOFLUZA is not effective in treating infections other than influenza. Other kinds of infections can appear like flu or occur along with flu and may need different kinds of treatment. Tell your healthcare provider if you feel worse or develop new symptoms during or after treatment with XOFLUZA or if your flu symptoms do not start to get better.
These are not all the possible side effects of XOFLUZA.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

How should I store XOFLUZA?

- Store XOFLUZA at room temperature between 68°F to 77°F (20°C to 25°C).
- Store XOFLUZA in the blister package that it comes in.

Keep XOFLUZA and all medicines out of the reach of children.
General information about the safe and effective use of XOFLUZA.
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What are the ingredients in XOFLUZA?
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Inactive ingredients: croscarmellose sodium, hypromellose, lactose monohydrate, microcrystalline cellulose, povidone, sodium stearyl fumarate, talc, and titanium dioxide.

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DISPATCHES FROM THE FRONT LINES OF SCIENCE AND INNOVATION

Strawberry Sex Ed

Unlike most plants, strawberries are either male or female. It's a botanical trick that new research suggests is made possible by sex-determining genes that "jump," or switch locations, over generations. Next up: trying to understand why.





ANIMALS

TAKING STOCK OF ANIMAL MILK

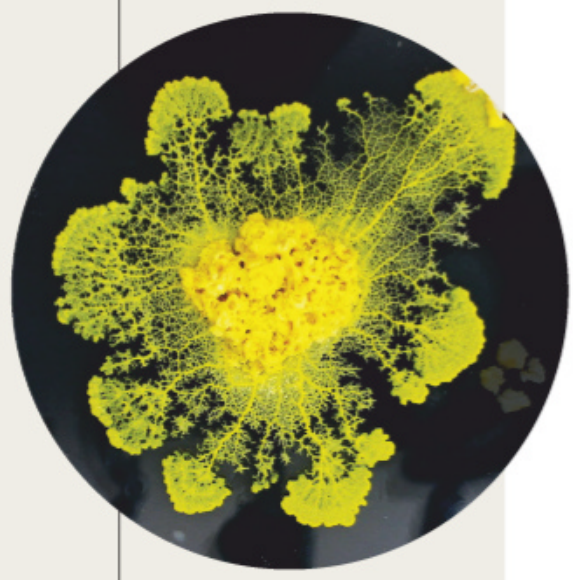
ONE ZOO'S FREEZERS FULL OF MILK HOLD CRUCIAL CLUES TO MAMMAL NUTRITION.

Since her baby was born last year, Calaya (above), a western lowland gorilla, has been allowing researchers to collect samples of her milk. Her contributions are part of a conservation effort at the Smithsonian's National Zoo, which maintains the world's most diverse repository of mammal milk. The bank, which contains milk from more than 200 species, has two purposes, says biologist Mike Power. The samples help the zoo develop nutritious formulas for animals that must be hand-reared. They also shed light on the origins of *Homo sapiens*. "The data we get from gorilla milk," he says, "help me understand how human milk has evolved." —CATHERINE ZUCKERMAN

BIOLOGY

Not-so-Simple Slime Mold

Though slime molds lack brains and neurons, the single-celled organisms still may be capable of basic forms of learning and adaptation. In studies led by biologist Audrey Dussutour, one slime mold species, *Physarum polycephalum,* exhibited the ability to overcome its aversion to certain things—a behavior known as habituation. In a later study, the slime mold then seemed to remember what it had learned. —CZ



PHOTOS (CLOCKWISE FROM LEFT): REBECCA HALE, NGM STAFF; BLOXSOME PHOTOGRAPHY/GETTY IMAGES; AUDREY DUSSUTOUR



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IMPORTED ECONOMIC POWER

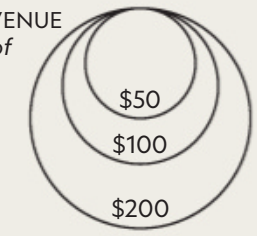
ENTREPRENEURIAL IMMIGRANTS have always contributed to U.S. economic growth: First- or second-generation Americans were instrumental in founding 44 of the top 100 *Fortune* 500 companies listed in 2018. The companies range from innovators such as Apple and Amazon to financial blue chips like AT&T and Procter & Gamble. The free-market economy provided opportunities—for immigrants and nonimmigrants alike—to create companies delivering new services, products, and visions of the future.

BY **SEAN McNAUGHTON** AND **KELSEY NOWAKOWSKI**

FROM IMMIGRANTS' DREAMS
Circles show the top 100 U.S. companies, sized by 2017 revenues. Those in color were founded or co-founded by an immigrant or a U.S.-born child of an immigrant. Notable founders are listed.

DATE FOUNDED
- 1790–1849: *6 companies*
- 1850–1899: *11*
- 1900–1924: *11*
- 1925–1974: *7*
- 1975–2017: *9*

2017 REVENUE
Billions of dollars





NOTE: IN COMPANIES FOUNDED BY MERGER, BREAKUP, OR SPIN-OFF, THE IMMIGRANT OR CHILD-OF-IMMIGRANT FOUNDER OF A PARENT COMPANY IS USED.

SOURCES: *FORTUNE;* STANDARD & POOR'S; PARTNERSHIP FOR A NEW AMERICAN ECONOMY; CENTER FOR AMERICAN ENTREPRENEURSHIP



NEW EPISODES
SUNDAYS 9/8c

NATIONAL GEOGRAPHIC

GENIUS

STEVE RAMIREZ

BY **RACHEL HARTIGAN SHEA**
PHOTOGRAPH BY **REBECCA HALE**



This Neuroscientist Makes Memories—and Suppresses Them

When Steve Ramirez was in college, he was fascinated by all kinds of subjects—from Shakespeare to piano, astronauts to medicine. That made choosing a major difficult, so he decided to "cheat," as he puts it. He would study "the thing that achieved everything that's ever been achieved": the brain. After he joined a lab researching the neuroscience of memory, he learned that every experience leaves physical traces throughout the brain. Those are memories, and they can be examined or even altered. "That idea enchanted me," he says.

Now Ramirez leads his own lab at Boston University, and he's figured out how to suppress bad memories by activating good ones. He and his team genetically engineer brain cells associated with memory in mice to respond to light. Then they create a bad memory—a mild electric shock—and watch the activated cells light up. Deactivating those cells would make the bad memory inaccessible or allow it to be overwritten by a good memory, such as social time with other mice.

Ramirez does not propose using this sort of "genetic trickery" to manipulate memories in humans. Instead, his discoveries about memory could inform how patients with post-traumatic stress disorder, anxiety, or depression are treated. "We want to understand how the brain works; we want to understand how memory works," he says. "It's like, the more we know how a car works, the better equipped we are to figure out what happens when it breaks down."



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IN THIS SECTION

A Beekeeper's Tools

The Inflated Charms of Magnificent Frigatebirds

Polar Bear Selfies—Lost and Found

ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY

NATIONAL GEOGRAPHIC | VOL. 235 NO. 2

TRIPLE THREATS

In Rocky Mountain National Park, 415 square miles of mountain terrain are protected—but not from effects of climate change. The average annual temperature in the high-elevation park increased 3.4˚F in the 20th century. That has worsened a trifecta of troubles—bark beetles, wildfires, and invasive plants such as cheatgrass—doing visible harm to the plant life covering three-fourths of the park.



Climate change leads to...

More cheatgrass

Increased wildfires

Bark beetle outbreaks

DOMINO EFFECT

Bark beetles, fires, and cheatgrass can play important ecological roles, but climate change exacerbates their effects on one another. For example, cheatgrass thrives when temperatures rise, adding kindling to wildfires that are already more intense due to drier conditions, and fires can spread faster where bark beetles have killed trees.

ATLAS BY **CLARE TRAINOR**

Mount Richthofen
12,940 ft
3,944 m

Source of the Colorado River

Long Draw Reservoir

Alpine Visitor Center

Ypsilon Mountain
13,514 ft
4,119 m

Hagues Peak
13,560 ft
4,133 m

Trail Ridge

Trail Ridge Rd.

Old Fall River Rd.

NATIONAL PARK

MUMMY RANGE

Black Canyon Ck.

Fern Lake fire (2012)

Cow Creek fire (2010)

34

36

Rocky Mountain National Park Headquarters

Estes Park
7,522 ft
2,293 m

Rocky Mountains

CO

ROCKY MOUNTAIN N.P.

UNITED STATES

N

SCALE VARIES IN THIS PERSPECTIVE. DISTANCE FROM ESTES PARK TO GRAND LAKE IS 18 MILES (29 KM).

Projected suitable cheatgrass habitat in 2050

Current suitable cheatgrass *(Bromus tectorum)* habitat

Wildfire over 50 acres since 1970

Severe bark beetle damage, 2012–18

INVADING GRASSES

Non-native cheatgrass, once limited to the park's lowest elevations, is now spreading above 9,500 feet, moving more than 2,000 feet in elevation in just 10 years.

WILDER WILDFIRES

More acreage has burned here in the past eight years than in the previous century. The 2012 Fern Lake fire, caused by humans and fed by dry conditions, burned for months and over snow.

DESTRUCTIVE BEETLES

Dense stands of conifers are like a banquet for bark beetles. Mountain pine beetles infest 90 percent of the park's pine forests, and spruce beetle populations are rising fast.

SOURCES: COLORADO STATE FOREST SERVICE; USDA FOREST SERVICE; NATIONAL PARK SERVICE; JASON SIBOLD AND AMANDA WEST, COLORADO STATE UNIVERSITY; GEOMAC, USGS



BEEKEEPER IN CHIEF



PHOTOGRAPH BY **REBECCA HALE**

THE WHITE HOUSE IS BUZZING—with bees. Beekeeper Charlie Brandts has tended several colonies since 2009, when then First Lady Michelle Obama wanted a hive to pollinate her garden. The honey is used in dishes served at the residence and is also given as gifts. Like all honeybee colonies, the ones at 1600 Pennsylvania Avenue have been susceptible to loss, so hive inspections and mite testing are among Brandts's routine tasks. Given the high-profile nature of his charges, however, this is not typical beekeeping, he says. "I do have to inform the Secret Service before I light my smoker." —CATHERINE ZUCKERMAN

1. Hive top feeder
Used for feeding sugar syrup to the bees in the fall so they have enough carbohydrates stored for winter.

2. Smoker
Puffs of cool smoke keep the bees calm during hive inspections or transport.

3. Veil
Zips to the jacket; netting protects a beekeeper's head—especially the eyes.

4. Jacket
Elastic cuffs and waistband help minimize stings and keep clothing clean.

5. Magnifying glass
For examination of cells deep inside a honeycomb.

6. Marking tube and paint
To make it easy to quickly identify the queen, a dot of paint is carefully applied to her thorax.

7. Wooden frames
Inside the hive box, removable frames provide structure to support honeycomb formation.

8. Honey
A jar of White House honey, harvested in the summer of 2011.

9. Hive tool
Good for removing frames from the hive box and for scraping and prying.

10. Hive closure board
The hive is closed during public events such as the annual Easter Egg Roll.

11. Paintbrush
During a honey harvest, a paintbrush makes quick, gentle work of clearing the bees away from frames.

12. Straw
Straw is used several ways: as fuel for the smoker and to help insulate and control moisture in the hive.

IS HIS IDEA OF SEX APPEAL INFLATED? YES. LITERALLY.

MANY A SUITOR puffs out his chest hoping to impress the ladies. But for hue, girth, and sheer musicality, none beats the blimplike bosom on *Fregata magnificens,* the magnificent frigatebird.

During a courtship display, each male seeks to outdo the others with one body part: a red pouch hanging from his throat. When he inflates this gular sac, it balloons into a heartlike shape as tall as he is. Then he clacks his beak, and it resonates in the sac like a drumbeat, a thrumming love call. "You hear it long before you see them," says Jen Jones of the Galapagos Conservation Trust, who has witnessed displays on the islands.

Females that have been gliding overhead land and eye their options. Males may turn up the heat even more with "disco moves, head shakes, or the occasional shimmy," Jones says. One study (right) says it's the drumming that gets males the most mates, but the whole show is "absolutely amazing," Jones says. "A feast for the senses." —PATRICIA EDMONDS

HABITAT/RANGE

Fregata magnificens chiefly inhabits the Americas' Pacific and Atlantic coasts and adjacent islands, from California and Georgia south to Ecuador and Uruguay.

CONSERVATION STATUS

The International Union for Conservation of Nature ranks the bird "least concern," but invasive species and habitat loss affect some populations.

OTHER FACTS

- Frigatebirds stay aloft for months at a time, riding thermal updrafts. They'll swoop to the ocean's surface to find food, Jones says, or steal it from other animals: "They're pirates, basically."
- Ecologists who studied male birds' courtship moves in Mexico concluded that the sound effects "significantly predict mating success." Males that drum at lower frequencies—thanks to larger gular sacs—and in quicker, more constant cadences appealed more to females, which may perceive them as more experienced or vigorous, the study says.



PHOTO: TUI DE ROY, MINDEN PICTURES

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The Shots That Almost Got Away



PHOTOGRAPHER AUDUN RIKARDSEN PLACED A CAMERA TRAP BESIDE AN ARCTIC BREATHING HOLE, HOPING TO CAPTURE THE PERFECT SHOT OF A SEAL. THEN A POLAR BEAR SHOWED UP—AND IT WAS EAGER TO INVESTIGATE.

STORY AND PHOTOGRAPHS BY
AUDUN RIKARDSEN



NOT TOO LONG AGO I was the guide on a wildlife-photography trip to Svalbard, an archipelago halfway between Norway's mainland and the North Pole. After two days of travel on a small passenger ship along the harsh and icy coast, we reached Hornsund fjord on the southern tip of Spitsbergen island. Wildlife is abundant in this remote and fragile area, and we were looking for seals and polar bears.

When we anchored the boat at the fjord ice, we spotted several seals resting on the ice, but no polar bears. I thought I'd try to get a picture of a seal as it came up for breath at a hole in the ice. I placed my camera and a motion sensor near the edge of a hole. The plan was that the motion sensor would fire the camera when the seal poked its head into the air. The image would capture the seal with the cold and hostile environment behind it.

On the way back to the ship, I wondered whether I should have anchored the camera, just in case. But returning to the hole would have disturbed the seals further and possibly prevented me from getting the shot. I decided not to do it.

Then, at two in the morning, a crew member woke us up. He had spotted a polar bear approaching in the distance under the midnight sun. We ran to the bow of the boat to see what would happen. At first the bear walked toward the boat. Then it turned and headed directly for my camera. I had long dreamed of taking a picture of a polar bear while it waited beside a breathing hole, hoping to grab a seal. I knew it would be a difficult photo to get, but here I could see it happening right in front of me, a dream very close to coming true.

The motion sensor reacted to the bear's movement, triggering the camera to start taking pictures. The bear circled the camera, gently sniffing and even licking it. Then the bear knocked the sensor onto the ice, grabbed the tripod, and tipped it and the camera into the hole. The camera hung from the sensor's cable. I prayed that it would stay that way so I could at least rescue the memory card containing the images.

The bear must have heard me. It took the sensor's cable in its mouth and started backing away from the hole, pulling the camera out.

Then the cable broke. My camera and the memory card with all those impossible-to-get close-ups of the polar bear disappeared more than 450 feet beneath the ice.

That was the worst moment in my photography career. I did not sleep well for a long time afterward. I was so angry with myself. I couldn't let it go. I started playing with the crazy idea of rescuing the camera. I tried to find someone who would help me find it, but my colleagues in polar research told me that the camera had most likely sunk into the soft mud commonly found in front of glaciers. I almost gave up.

A year later I was asked to join a similar trip to the same spot on the same boat. I obtained permission to bring a remotely operated vehicle (ROV) and a

colleague to pilot it. We would try to find the camera. If we didn't succeed, I would know I had at least tried. Maybe I would then be able to stop thinking about that camera. I hate to give up.

When we arrived back at Hornsund fjord, we were given only four hours for the operation due to the paying customers on board. There was a lot more fjord ice in front of the glacier than there had been on the previous trip, and we wondered whether it would be safe to walk so far from the boat. As I knew well, polar bears could be nearby. We decided to risk it. The ice was so thin that it bent beneath us. We almost turned back several times, but then we managed to find a safe route to where my camera had disappeared one year earlier. Now we just had to find it.

We ran into technical difficulties almost immediately and had to pull the ROV out of the water twice. The water was murky, so we couldn't see to steer the ROV, and the tidal current was causing it to drift from the site. Our only chance of finding the camera was by landing the ROV on top of it, which seemed like a long shot.

Then, like a miracle, on the third try the ROV found the camera. We shouted and danced around on the ice.

Our celebration was premature. When we tried to grab the camera, the ROV's cable became tangled. The claw on the ROV's arm was less than an inch from the camera—close but not close enough to grab it. We could hear the arm scratch against the camera's sides.

Then we lost control of the ROV. The pilot was sure it was broken. I was even more frustrated than I had been the year before. I wondered if it would have been better if we had never found the camera at all.

We retrieved the ROV and saw that the propellers were jammed with seaweed. We had just enough time for one more try. Amazingly we managed to place the ROV on the camera a second time. This time the claw clamped securely onto the tripod. We got the camera up on the ice, and I screamed as loudly as I could.

The camera was corroded, but I managed to get the memory card out. I immediately put it into distilled freshwater to prevent further corrosion. I kept it there until I returned to the mainland. Then I contacted a company that retrieves lost electronic data in crime cases. They managed to retrieve all 149 of my photos.

It was amazing to see them. I saw the polar bear breathing. I saw it licking the lens until the lens became blurry. I saw it prod the lens with its massive, furry white paw. And, at the end, I saw the looming edge of the breathing hole.

Retrieving that camera is by far the most satisfying accomplishment of my photography career. I have never experienced such a massive burst of adrenaline as I did when we pulled that camera out of the water and onto the ice. ▯

Audun Rikardsen is a nature photographer as well as a professor of freshwater and marine biology at UiT—The Arctic University of Norway. This is his first story for *National Geographic*.

UNDER THE MIDNIGHT SUN, beside a hole in the Arctic ice, a polar bear found something new—Audun Rikardsen's camera and motion sensor. The bear sniffed the camera, pawed at it, and knocked it into the water. One year later Rikardsen went on an expedition to get it back.













Protecting the planet's precious predators

As a National Geographic wildlife photographer, Shannon Wild is accustomed to breathtaking encounters, but floating above the epic landscapes of Zambia's Kafue National Park took her latest assignment to another level, literally.





"That beautiful, gentle movement of a hot air balloon gives you wonderful opportunities to witness animals undisturbed by your presence," explains Shannon. "This was a really special experience for me: mind-blowing."

From the air, the vast expanse of the Greater Kafue Ecosystem is brought into focus.

Zambia's largest and oldest national park covers 8,650 square miles of swaying golden savannahs, seasonal floodplains and lush forests.

Such diverse, untamed space makes Kafue a magnet for wildlife, but also provides the park's biggest challenge: how to protect vulnerable species in a region bigger than Wales.

"This ecosystem supports large numbers of predators including lions, wild dogs and cheetahs, providing the continuous expanse of unfragmented, protected land these carnivores need to thrive," says Shannon. "Kafue's a massive park and even in an open area, they're perfectly camouflaged."

Despite this, these animals have to navigate threats from snares, poaching, human conflict and disease so gathering data on their movements and behaviour is essential for their survival.

"The Zambian Carnivore Programme (ZCP; zambiacarnivores.org) monitors Kafue's large carnivores using advanced satellite tracking collars funded by Gemfields," explains Shannon.

The data extracted from the collars means that if an animal is snared, sick or heading for a potentially deadly human encounter, the ZCP team can work with the Zambian Department of Wildlife to swiftly locate the animal and assist.

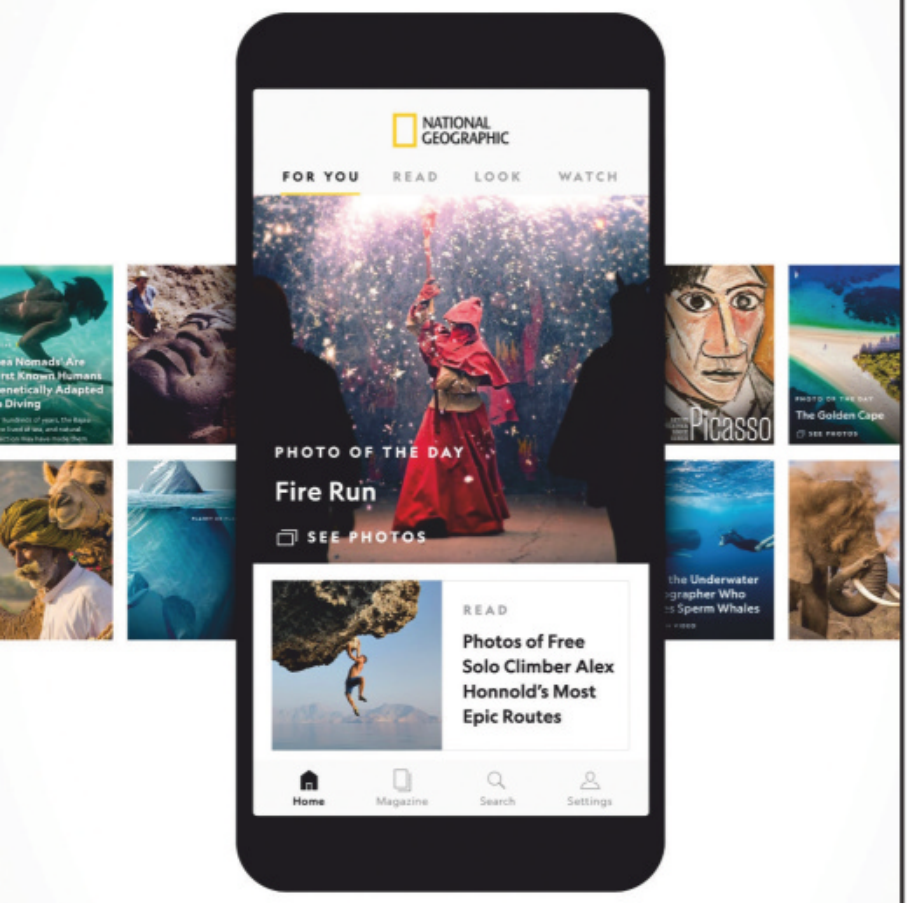
"ZCP contributes life-saving research about these predators," says Shannon. "They're all social to a degree, so by fitting just one animal with a collar, the team can follow and extrapolate information on the whole group. It's opened up a new window on their world."

All images: Shannon Wild

Gemfields is the world's leading supplier of responsibly sourced coloured gemstones. They work with conservation partners such as the Zambian Carnivore Programme who tirelessly aim to smooth the relationship between Africa's carnivores and local communities across vast, remote and challenging areas. **gemfields.com**

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Purchasers of Charmin Freshmates Flushable Wipes: A Class Action Settlement May Affect Your Rights

WHO IS AFFECTED

A class action settlement has been reached involving Charmin Freshmates Flushable Wipes. The settlement involves all pre-moistened wipes sold under the Charmin brand name bearing the word "flushable" on the package label ("Wipes"). The lawsuit claims that the Wipes are not actually flushable. The Procter & Gamble Company ("P&G") denies these allegations and maintains that the Wipes perform as advertised. You may be an eligible class member if you purchased the Wipes anywhere in the United States, except the State of New York, between April 6, 2011 and November 26, 2018.

WHAT DOES THE SETTLEMENT PROVIDE?

In connection with this settlement, P&G will change the labeling of the Wipes and agreed to stricter industry-standard testing protocols. P&G will also provide a sixty cent ($0.60) per-package refund, up to $4.20 household maximum, to class members without proof of purchase. A $30.00 household maximum will be paid for claims submitted with a proof of purchase. Proof of purchase means an itemized sales receipt originally generated by a retail seller showing the date and place of purchase, name of the product purchased, and the amount paid. Proof of purchase can be provided in the form of a photocopy or digital image file (e.g., PDF, JPG, TIF).

WHAT ARE MY OPTIONS?

You must **submit a claim** online by February 28, 2019 or by mail so that it is *received* (not merely postmarked) no later than February 28, 2019 to receive a payment. You can **opt out of the class** by February 28, 2019 and keep your right to sue P&G on the released claims. The settlement will release all claims related to Plaintiffs' contentions that P&G's marketing, advertising, and sale of the Wipes with the representations "flushable," "septic safe," and "safe for sewer and septic systems" were false or misleading. There is no release of claims for personal injury or property damage allegedly caused by use of the Wipes. You can also **object to the settlement** by February 28, 2019. For details on how to opt out, object, or to file a claim, please visit www.PettitWipeSettlement.com or contact the Claim Administrator. If you **do nothing**, you will not receive a payment and you will be bound by the decisions of the Court.

COURT HEARING AND ATTORNEYS' FEES

The Court will hold a hearing on March 28, 2019 at 1:30 p.m. to consider whether to approve the settlement. If the settlement is approved, the attorneys for the class will ask the Court for an award from P&G of up to $2,150,000 in fees, costs, and expenses, and class representative payments of $1,000 to $5,000 for each of the named plaintiffs. Note that the hearing date may change without further notice to you. You may attend the hearing, but you do not have to. Plaintiffs' Motion for Attorneys' Fees and Costs will be posted on the website after it is filed.

MORE INFORMATION

This is only a Summary. For more information, please visit: www.PettitWipeSettlement.com, or contact the Claim Administrator by calling 1-833-305-3913 or by writing to Pettit v. Procter & Gamble, c/o Claim Administrator, PO Box 58280, Philadelphia, PA 19102-8280. You may also contact Plaintiffs' counsel, Gutride Safier LLP, 100 Pine Street, Suite 1250, San Francisco, CA 94111. The case name is *Pettit et al. v. Procter & Gamble Company*, U.S. District Court for the Northern District of California, Case No. 3:15-cv-02150-RS.

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FEATURES



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‘WHAT GOLD MEANT TO EARLIER ERAS, AND PETROLEUM TO THE PREVIOUS CENTURY, LITHIUM MAY ECLIPSE IN THE COMING YEARS.’

At the Salar de Uyuni salt flat that conceals vast lithium deposits in Bolivia, an Aymara woman escorts two llamas back to the herd.

PHOTO: CEDRIC GERBEHAYE





With California's Yosemite Valley far beneath him, Alex Honnold free solos—which means climbing without ropes or safety gear—up a crack on the 3,000-foot southwest face of El Capitan. Before he accomplished the feat on June 3, 2017, Honnold spent nearly a decade thinking about the climb and more than a year and a half planning and training for it.

2

HOW ALEX HONNOLD MADE A HISTORIC CLIMB UP 'A FREAKING-BIG WALL' WITHOUT ROPES— AND LIVED TO TELL ABOUT IT

FREE

BY **MARK SYNNOTT**

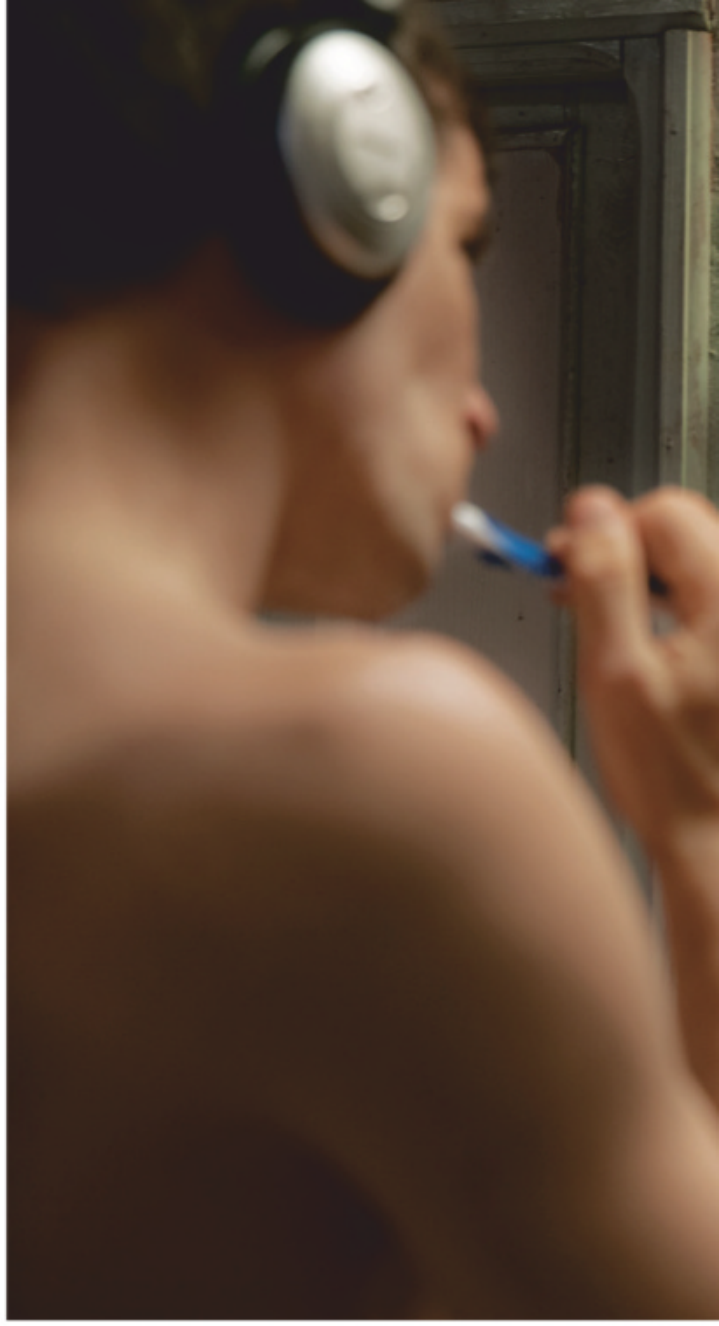
PHOTOGRAPHS BY **JIMMY CHIN**





Honnold peers over the edge of Taft Point, across the Yosemite Valley from the granite escarpment known as El Capitan. Each year Honnold devotes several months to climbing the park's iconic walls and boulders. "Yosemite," he says, "is my favorite place in the whole world."

It's 4:54 a.m. on a chilly November morning in 2016 in Yosemite National Park.



A full moon casts an eerie glow onto the southwest face of El Capitan, where Alex Honnold clings to the side of the granite wall with nothing more than the tips of his fingers and two thin edges of shoe rubber. He's attempting to do something that professional rock climbers have long thought was impossible—a "free solo" ascent of the world's most iconic cliff. That means he is alone and climbing without a rope as he inches his way up more than half a mile of sheer rock.

A light breeze rustles his hair as he shines his headlamp on the cold, smooth patch of granite where he must next place his foot. Above him, for several feet, the stone is blank, devoid of any holds. Unlike parts of the climb higher up, which feature shallow divots, pebble-size nubs, and tiny cracks that Alex can claw himself up with his freakishly strong fingers, this part—a barely less than vertical slab on a section called the Freeblast—must be mastered with a delicate balance of finesse and poise. Climbers call it friction climbing. "It's like walking up glass," Alex once said.

He wiggles his toes. They're numb. His right ankle is stiff and swollen from a severe sprain he sustained two months earlier when he fell while practicing this part of the route. That time he was attached to a rope. Now, falling isn't an option. Free soloing isn't like other dangerous sports in which you might die if you screw up. There is no "maybe" when you're 60 stories up without a rope.

Six hundred feet below, I sit on a fallen tree watching the tiny halo of Alex's light. It hasn't moved in what feels like an eternity but is probably less than a minute. And I know why. He's facing the move that has haunted him ever since he first dreamed up this scheme seven years ago. I've climbed this slab myself, and the thought of doing it free solo makes me nauseated. The log on which I'm sitting lies less than a hundred yards from where Alex will land if he slips.

A sudden noise jolts me back to the present. My heart skips. A cameraman, part of the crew recording the feat, hustles up the trail toward the base of the wall. I can hear the static of his walkie-talkie. "Alex is bailing," he says.

Thank God, I think. Alex will live.

I will talk to him later, but I already know why he's backing off. He's not feeling it. Of course he isn't—it's madness. Maybe, I let myself consider, this isn't meant to be.

SOME IN THE CLIMBING WORLD view free soloing as something that isn't meant to be. Critics regard it as reckless showmanship that gives

WATCH THE *FREE SOLO* TV PREMIERE
The critically acclaimed documentary detailing Alex Honnold's historic climb airs March 3 at 9 p.m. on National Geographic.

LEFT

Honnold, 33, listens to music while brushing his teeth as he prepares for a day of climbing in Morocco's High Atlas Mountains, one of several foreign locations where he trained for his attempt on El Capitan.

BELOW

For a free soloist, finger strength can mean the difference between life and death. Leading up to his climb, Honnold performed a 90-minute "hangboarding" routine every other day in his van, which for years has served as a home and mobile base camp.





Attached to ropes, Honnold practices a section of Freerider, the route he would free solo up El Capitan.

Freerider tests every part of a climber's body—from fingers to toes—as well as mental and physical stamina.

the sport a bad name, noting the long list of those who've died attempting it. Others, myself included, recognize it as the sport's purest expression. Such was the attitude of an Austrian alpinist named Paul Preuss, considered by climbing historians to be the father of free soloing. He proclaimed that the very essence of alpinism was to master a mountain with superior physical and mental skill, not "artificial aid." By age 27, Preuss had made some 150 ropeless first ascents and was celebrated throughout Europe. Then, on October 3, 1913, while free soloing the North Ridge of the Mandlkogel in the Austrian Alps, he fell to his death.

But Preuss's ideas would live on, influencing successive generations of climbers and inspiring the "free climbing" movement of the 1960s and '70s, which espoused using ropes and other gear only as safety devices, never to assist a climber's upward progress. The next serious free soloist of note appeared in 1973, when "Hot" Henry Barber shocked the climbing community by scaling the 1,500-foot north face of Yosemite's Sentinel Rock without a rope. Three years later, John Bachar, a 19-year-old from Los Angeles, free soloed New Dimensions, an arduous 300-foot crack in Yosemite. No one upped the ante until 1987, when Peter Croft, an unassuming Canadian, free soloed two of Yosemite's most celebrated routes—Astroman and Rostrum—back-to-back in the same day.

Croft's achievement stood until 2007, when a shy, doe-eyed 22-year-old from Sacramento named Alex Honnold showed up in Yosemite Valley. He stunned the climbing world by repeating Croft's Astroman-Rostrum masterpiece. The next year he free soloed two famously tough routes—Zion National Park's Moonlight Buttress and the Regular Northwest Face of Yosemite's Half Dome—climbs so long and technically difficult that no serious climber had imagined they could be scaled without a rope. As sponsorship offers poured in and journalists and fans hailed his achievements, Alex was secretly contemplating a much bigger goal.

IT'S IMPORTANT TO NOTE that Alex's quest to free solo El Capitan wasn't some adrenaline-fueled stunt that he'd come up with on a whim.

No Ropes Attached

On June 3, 2017, Alex Honnold free soloed the Freerider route on El Capitan, Yosemite's 3,000-foot southwest face. He completed the route in less than four hours. It's a vertical obstacle course that can take veteran climbers using ropes several days to ascend. Honnold spent a year choreographing thousands of precise moves to get through a gantlet of physical and nerve-testing challenges.

The Five Most Challenging Sections

Enduro Corner
Honnold used a "layback" technique, pulling on the edge of a narrow crack while pushing his feet against an adjacent wall.
Length of section: **180 ft**
Honnold practiced this section with ropes: **>40 times**

Boulder Problem
One move on the most difficult section required him to cling to a pea-size nub while "karate kicking" one leg to reach a toehold.
Length of section: **150 ft**
Practiced: **>60 times**

Monster Offwidth
After wedging half his body into a vertical crack six to 12 inches wide, he wriggled his way upward.
Length of section: **200 ft**
Practiced: **>10 times**

Hollow Flake
He climbed down 90 feet to reach a large crack. Other climbers avoid this detour by using ropes to swing to the crack.
Length of section: **280 ft**
Practiced: **>10 times**

Freeblast slabs
Honnold had to smear his shoe rubber against the smooth rock and maintain perfect balance. He quit here on his first solo try.
Length of section: **200 ft**
Practiced: **>90 times**

El Capitan summit
7,569 ft (2,307 m)

End elevation: 7,173 ft

Completes climb at 9:28 a.m. (total: 3 hrs, 56 mins)

Round Table Ledge

The Traverse

8:55 a.m. **Enduro Corner**

The Block

Honnold to scale

Teflon Corner

8:24 a.m. **Boulder Problem**
Honnold chooses this option to avoid the glass-slick faces along Teflon Corner.

El Cap Spire

7:36 a.m. **Monster Offwidth**

The Ear
Instead of looping up around the Ear, he traverses left to avoid a tricky down climb.

The Heart

While crossing this ledge, he wakes a roped climber in a pink unicorn suit.

6:49 a.m. **Hollow Flake**

Lung Ledge

Mammoth Terraces

Heart Ledges

Half Dollar

Triangle Ledge

6:04 a.m. **Freeblast slabs**

Dots mark pitches, which are sections measured by one rope length during a typical climb.

Base elevation: 4,208 ft

Starts Freerider route at 5:32 a.m.

Level of difficulty of each section
Elite
Expert
Moderate







EL CAPITAN
Southwest Face

DAISY CHUNG, NGM STAFF. EL CAPITAN ART: MARTIN GAMACHE, NGM STAFF; CLAY WADMAN; ALDO CHIAPPE. SOURCES: MARK SYNNOTT; ALEX HONNOLD; GREG STOCK, YOSEMITE NATIONAL PARK; SOFIA GELD, LITTLE MONSTER FILMS

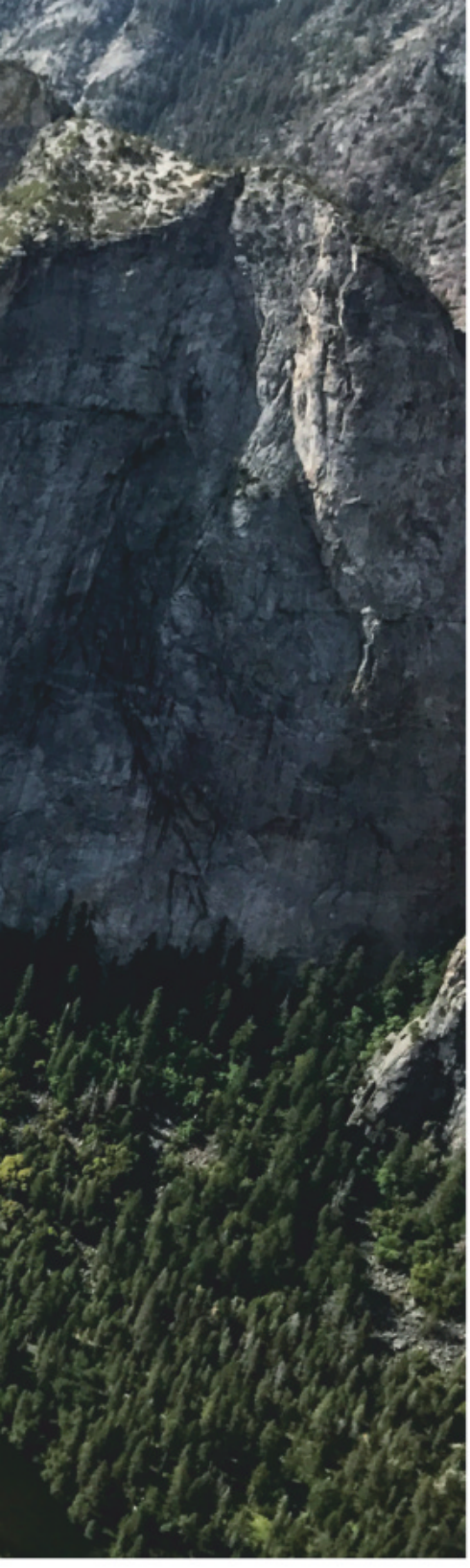


In 2009, during our first climbing expedition together, he mentioned the idea to me. I thought he was totally crazy, but there was something about his supreme confidence and the way he effortlessly moved up mind-bendingly difficult rock faces that made the comment seem like more than just an idle boast.

Alex researched several El Capitan routes, finally settling on Freerider, a popular test piece for veteran climbers and one that usually requires multiple days to ascend. Its 30 or so pitches—or rope lengths—challenge a climber in practically every possible way: the strength of fingers, forearms, shoulders, calves, toes, back, and abdomen, not to mention balance, flexibility, problem solving, and emotional stamina. Certain times of the day the sun heats the rock so that it burns to touch it; hours later the temperature can plummet below freezing. Storms blow in, powerful thermal updrafts lash the wall, springs leak out of cracks. Bees, frogs, and birds can burst from crevices during crucial moves. Rocks of all sizes can suddenly give way and tumble down.

The Freeblast may be the scariest part, but more physically demanding sections await higher up: a chimney-like crack he'll have to squirm through; a wide gap where he'll have to perform almost a full split, pressing the rock with his feet and hands to inch his way up. And then 2,300 feet above the valley floor is the route's crux—called the Boulder Problem—a blank face that requires some of the most technically challenging moves of the climb.

Over a year, Alex spent hundreds of hours on



Holding all his climbing gear—his shoes and bag of chalk—Honnold stands atop El Capitan four hours after he began scaling it. "At the bottom, I was a little nervous," he said afterward. "I mean, it's a freaking-big wall above you." So what's next? "I still want to climb hard things. Someday. You don't just retire as soon as you get down."

Freerider, attached to ropes, working out a precisely rehearsed choreography for each section, memorizing thousands of intricate hand and foot sequences. Afterward he'd retreat to "the box," a RAM ProMaster van. (Vans have served as his mobile base camp and home, off and on, for the past 12 years.) There he would record each day's training details in spiralbound notebooks.

"So how did it go up there?" I ask him one evening, as he's preparing a vegan meal in the kitchenette of his van. He'd been rehearsing the Boulder Problem that day.

"I've done it 11 or 12 times now without falling," he replies. "But it's definitely something you have to get psyched up for." He pantomimes the 11-move sequence for me. Later he describes it move by move in his own special argot: "Left foot into the little thumb sprag crack thing. Right foot into this little dimple that you can toe in on pretty aggressively so it's opposing the left hand, then you can, like, zag over across to this flat, down-pulling crimp that's small but you can bite it pretty aggressively. I palm the wall a little bit so I can pop my foot up and then reach up to this upside-down thumb sprag crimp thing."

"How big is that hold?" I ask.

"It's the worst hold on the route." Alex looks at me with his eyes open wide, holding his thumb and forefinger about an eighth of an inch apart. "It's maybe this big."

But before he could tackle the Boulder Problem, he'd have to get over the Freeblast, which was proving to be the most vexing variable in this life-or-death equation. I join him on one of those roped training sessions, and on the pitch where he'd stopped in November, he slips once again. By my tally, it's the third time he has fallen here. "That move is really insecure. I don't like it," he tells me as we pause at a point just above slab. At that moment, I realize that Alex will never have this section mastered to his satisfaction—no matter how many times he rehearses. It's the one move on the route that he can't bully into submission. And he must know it too.

SATURDAY MORNING, JUNE 3, 2017, seven months after Alex's aborted attempt, I'm in the meadow near the foot of El Capitan. The tall grass is covered with dew. The sky is gray, as it always is just before dawn. The only sound is a faint rustle of wind in the tall pine trees. I squint through a telescope, and there is Alex, 600 feet above the valley floor, moving up onto the Freeblast, the glassy slab that has tormented him for nearly a decade. His movements, normally so smooth, are worrisomely jerky. His foot tap-tap-taps against the wall as if he's feeling his way tentatively into the slab. And then, just like that, he's standing on a ledge several feet above the move that has been hanging over his head for years. I realize I've been holding my breath, so I consciously exhale. Thousands of moves are still to come, and the Boulder Problem looms far above, but he won't be turning back this time. Alex Honnold is now well on his way to completing the greatest rock climb in history. ▯

Mark Synnott wrote about climbing sea cliffs in Oman with Alex Honnold for the January 2014 issue. Photographer **Jimmy Chin** co-directed the National Geographic documentary *Free Solo*.



BY **KRISTIN ROMEY**

PHOTOGRAPHS BY **ROBERT CLARK**



An Unthinkable Sacrifice

MORE THAN 500 YEARS AGO
THE CHIMÚ PEOPLE,
IN WHAT IS NOW PERU,
KILLED 269 BOYS AND GIRLS
IN SHOCKING RITUALS.
WHY?
IT'S A MYSTERY.

A headdress of macaw feathers adorns the skull of a sacrificed child who had shoulder-length hair.

Researchers say the headdress indicates the youth may have been from an elite family.
REBECCA HALE, NGM STAFF



The remains of two children, perhaps a boy and a girl, rest beside each other at a mass burial site on the arid coast of northern Peru. They are among the 269 children who were sacrificed and buried around A.D. 1450 at two sites near Chan Chan, the ancient capital of the Chimú people. Most of the victims were killed with a cut to the chest, possibly to remove the heart, and buried in simple shrouds.







Fourteen-year-old Danila holds a baby alpaca near Huaylillas in the highlands of northern Peru. Skeletal analysis of the sacrificed children reveals that they were between the ages of five and 14 and came from throughout the Chimú Empire, including the highlands.

The young victim lies in a shallow grave in a vacant lot strewn with trash. It's the Friday before Easter here in Huanchaquito, a hamlet on the north coast of Peru.

The throb of dance music, drifting up from seaside cafés a few hundred yards to the east, sounds eerily like a pulsing heart. It's accompanied by the soft *chuf, chuf* of shovels as workers clear away broken glass, plastic bottles, and spent shotgun shells to reveal the outline of a tiny burial pit cut into an ancient layer of mud.

Two college students—archaeologists in training, wearing hospital scrubs and masks—splay on their stomachs on either side of the grave and begin digging with trowels.

The first thing to appear is the crest of a child's skull, topped with a thatch of black hair. Switching from trowels to paintbrushes, the excavators carefully sweep away the loose sand, exposing the rest of the skull and revealing skeletal shoulders



Local pizza shop owner Michael Spano holds a photograph of one of the first children excavated at Huanchaquito. Spano alerted archaeologist Gabriel Prieto to the bones eroding from the vacant lot across from his house, urging him to excavate the site. "You'll be famous," Prieto recalls Spano telling him.

The nonprofit National Geographic Society helped fund fieldwork for this article.



poking through a coarse cotton shroud. Eventually the remains of a tiny, golden-furred llama come into view, curled alongside the child.

Gabriel Prieto, a professor of archaeology from the National University of Trujillo, peers into the grave and nods. “Ninety-five,” he announces. He’s keeping a running tally of victims, and this one, labeled E95, is the 95th dug up since he first began investigating the mass burial site in 2011. The grim count from this and a second sacrifice site nearby will ultimately add up to 269 children between the ages of five and 14 and three adults. All of the victims perished more than 500 years ago in carefully orchestrated acts of ritual sacrifice that may be unprecedented in world history.

“This is something completely unexpected,” exclaims Prieto, shaking his head in bewilderment. The words have become a kind of mantra as the archaeologist and father struggles to make sense of the harrowing discovery at a site called Huanchaquito-Las Llamas. In our time and culture, the violent death of even one child rends all but the most callous hearts, and the specter of mass murder horrifies every healthy mind. And so, we wonder: What desperate circumstances might account for an act that’s unthinkable to us today?

ARCHAEOLOGISTS HAVE FOUND evidence of human sacrifice in all parts of the world. Victims may number in the hundreds, and often they’re deemed to have been prisoners of war,





Archaeologists Gabriel Prieto (with brush, propped on an elbow) and John Verano (at far left, with camera) work with their team to uncover shallow graves at Huanchaquito. Soon after excavations concluded here, archaeologists discovered a second child sacrifice site at nearby Pampa la Cruz.





Archaeology students at the National University of Trujillo prepare to clean and catalog skulls from the mass burial at Huanchaquito. The arid climate of northern Peru naturally mummified many of the remains, which are unusually well preserved.

The hoofprints of young llamas are preserved in a deep layer of mud around the grave of a sacrificed child at Huanchaquito. Evidence of heavy rain on the arid coast has led researchers to suggest that the mass sacrifice of children may have been a desperate response to flooding caused by an El Niño.

The remains of a child and baby llama emerge from the sand at Huanchaquito. Most children there were buried facing the sea, while the llamas faced the Andean peaks. The youths represented the Chimú's future. Llamas were costly offerings as well—valuable sources of food, transport, and fiber.

GABRIEL PRIETO

Archaeologists have found signs of human sacrifice at sites around the world. But evidence of mass killings of children, like what was found at Huanchaquito-Las Llamas, is rare.

or casualties of ritual combat, or retainers killed upon the death of a leader or the construction of a sacred building. Ancient texts, including the Hebrew Bible, attest to the practice of child sacrifice, but clear evidence of mass killings of children is rare in the archaeological record. Until the discovery at Huanchaquito (pronounced wan-cha-KEE-toe), the largest known child sacrifice site in the Americas—and possibly the entire world—was at Templo Mayor in the Aztec capital of Tenochtitlán (modern-day Mexico City), where 42 children were slain in the 15th century.

Prieto grew up in Huanchaco (pronounced wan-CHA-co), the town that encompasses Huanchaquito. As a child, he hunted for beads outside the 16th-century Spanish colonial church that perches on the town's highest hill. He recalls spending afternoons on the southern edge of town exploring the adobe ruins of Chan Chan, the ancient capital of the Chimú people. At its peak in the 15th century, Chan Chan was one of the largest cities in the Americas, the seat of power for an empire that stretched some 300 miles along the Peruvian coast.

Those childhood experiences inspired Prieto to become an archaeologist, and while earning a doctorate from Yale, he returned to his hometown to excavate a 3,500-year-old temple.

Then in 2011 the owner of a local pizza shop shared startling news: His children—and the neighborhood dogs—were finding human bones sticking out of the sand of a nearby vacant lot. He implored the archaeologist to investigate.

At first Prieto thought the site was simply a long-forgotten cemetery. But after recovering the remains of several children wrapped in shrouds—remains that radiocarbon analysis dated to between A.D. 1400 and 1450—the archaeologist realized that he had stumbled onto a much bigger discovery.

The burials, Prieto noticed, weren't typical of the Chimú. The children were interred in unusual positions—prone on their backs or curled on their sides instead of sitting upright, as was customary—and they lacked the adornments, pottery, and other grave goods commonly found in Chimú burials.

Instead, many were buried alongside very young llamas and possibly alpacas. As vital sources of food, fiber, and transport, these Andean animals were among the Chimú's most valuable assets. And finally there was this: Many of the children and animals had visible cut marks across their sternum and ribs.

To help make sense of the clues, Prieto called John Verano, a biological anthropologist and forensic expert at Tulane University. Verano has decades of experience analyzing physical evidence of ritual violence in the Andes, including a 13th-century Chimú massacre of some 200 men and boys at the site of Punta Lobos.

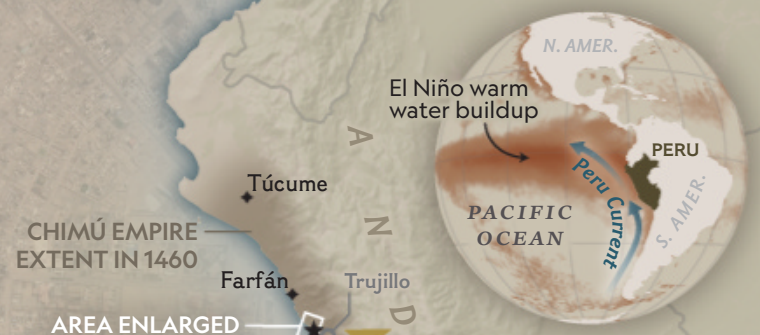
After examining the remains from Huanchaquito, Verano confirmed that the children and animals were deliberately killed in the same manner—with a horizontal cut across the sternum, likely followed by removal of the heart. He found the consistency of the cut location, as well as the absence of any "hesitation marks"—stop-starts of the knife blade—on the bones especially striking. "It's ritual killing, and it's very systematic," he said.

But reconstructing events at Huanchaquito is difficult, mainly because archaeologists and historians know very little about the Chimú. Theirs may be the greatest empire that few have ever heard of, bookended in history by two civilizations that loom much larger in the popular imagination: the Moche, whose stunning murals depict the bloody sacrifice of war captives, and the Inca, who vanquished the Chimú around 1470, only to be conquered by Spanish invaders little more than 60 years later.

The Chimú left no written records, so other than archaeological findings, what little is known of them comes from Spanish chronicles. Those accounts claim that the Inca sacrificed hundreds of children *(Continued on page 76)*

DIRE THREATS, DRASTIC MEASURES

By the 15th century the Chimú Empire was struggling for survival. Evidence of unusually destructive rain events likely caused by El Niño disruptions, as well as the threat of an Inca invasion, may have pushed Chimú leaders to take desperate, and in the end futile, steps: sacrificing hundreds of children and llamas at two sites known today as Pampa la Cruz and Huanchaquito-Las Llamas.

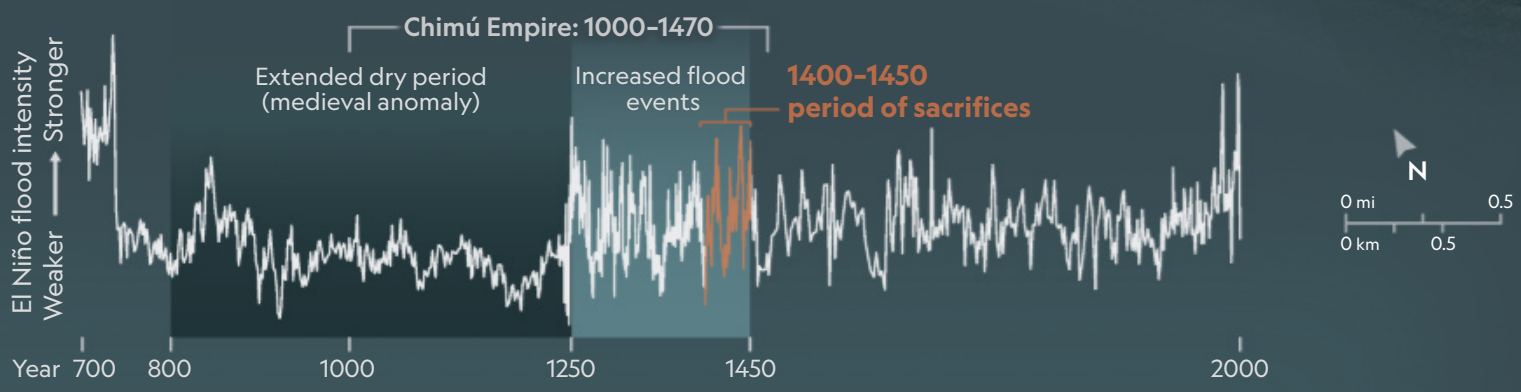


Túcume
CHIMÚ EMPIRE EXTENT IN 1460
Farfán
Trujillo
AREA ENLARGED
CHAN CHAN
Manchán
ANDES
PERU
PACIFIC OCEAN
LIMA
CUSCO
INCA EMPIRE
0 mi 100
0 km 100

Impending invasion
The Inca were expanding northward, closer to the Chimú. The Chimú capital, Chan Chan, would ultimately fall to Inca forces around 1470.

Pampa la Cruz
132 Children
260 Llamas
69 ft 21 m
HUANCHACO
Las Llamas
137 Children
206 Llamas
36 ft 11 m
HUANCHAQUITO
CHAN CHAN ARCHAEOLOGICAL COMPLEX
PAN-AMERICAN HWY.
PACIFIC OCEAN

Wrath of the weather gods
South America's west coast had experienced recurring El Niño flooding for centuries. But the Chimú emerged during an unusually long and stable dry period known as the medieval anomaly. When that ended, their troubles began.



SOREN WALLJASPER, NGM STAFF; PATRICIA HEALY
SOURCES: DIGITALGLOBE; TERRAMETRICS; GABRIEL PRIETO, NATIONAL UNIVERSITY OF TRUJILLO, PERU; JERRY D. MOORE, CALIFORNIA STATE UNIVERSITY, DOMINGUEZ HILLS; BERT REIN, GEOCONSULT REIN; DANIEL SANDWEISS, UNIVERSITY OF MAINE; NOAA

A Chimú executioner awaits a young victim in an artist's reconstruction of the mass sacrifice at Huanchaquito. Archaeologists found no evidence that the children were bound, but they may have been given chicha, or corn beer, to make them listless and compliant during the terrifying ritual.

ART: SAMSON GOETZE. MÓNICA SERRANO, NGM STAFF; PATRICIA HEALY.
SOURCES: GABRIEL PRIETO, NATIONAL UNIVERSITY OF TRUJILLO; JOHN W. VERANO, TULANE UNIVERSITY; NICOLAS GOEPFERT, FRENCH NATIONAL CENTER FOR SCIENTIFIC RESEARCH; ANNE POLLARD ROWE





Rare depictions of the Chimú pantheon adorn textiles found in elite burials at Pampa la Cruz (1). Carved wooden figures bear stylized images of humans or gods (2, 3, 4), but archaeologists were surprised that the children were buried with few artifacts. The figure holding a cup (3) may be offering chicha, the corn beer prepared in vessels such as this one (5), found at Huanchaquito.

REBECCA HALE, NGM STAFF (1)



2



3



4



5

A copper knife found at Pampa la Cruz, the first discovery of its kind, includes a rattle that would have sounded as the blade was drawn across the victim's chest. The center segment of a child's unfused breastbone (right) was sliced cleanly in two, clear evidence of methodical, ritual killing.

REBECCA HALE, NGM STAFF (KNIFE)





Killing children and young llamas—very precious assets to the kingdom—may have been an effort to persuade the gods to stop the rain that had brought chaos to the Chimú.

upon the installation or death of a king—an assertion for which there is as yet no archaeological evidence—but they offer no hint that the Chimú practiced child sacrifice on a similar scale. "Until now, we had no idea that the Chimú did anything like that," Verano says, referring to the unprecedented number of victims. "It's the luck of archaeology."

ONE MAJOR CLUE to what happened at Huanchaquito is the thick layer of ancient, dried mud in which the sacrificial victims were buried. Deep mud means heavy rain, and on the arid coast of northern Peru, "such rains usually only come with El Niño," Prieto explains.

Chan Chan's population was sustained by carefully managed irrigation systems and coastal fisheries, both of which could have been thrown into disarray by the higher sea temperatures and heavy downpours associated with the climatic event. A severe El Niño, the researchers theorize, may have shaken the political and economic stability of the Chimú kingdom. Its priests and leaders may have ordered the mass sacrifice in a desperate attempt to persuade the gods to stop the rain and the chaos.

"This number of children, this number of animals—it would have been a massive investment on behalf of the state," Prieto says.

Jane Eva Baxter, an anthropology professor at DePaul University who specializes in the history of children and childhood, agrees that the Chimú may have considered their children among the most valuable offerings they could present to the gods.

"You're sacrificing the future and all that potential," she says. "All of the energy and effort that's gone into continuing your family, continuing your society into the future—you're taking that away when you take a child."

Offering children also may represent an evolution in the way pre-Columbian societies in northern Peru sought to win favor in the spirit world.

Haagen Klaus, a professor of anthropology at George Mason University, points out that child sacrifice became more common in the region after the fall of the Moche (the culture that preceded the Chimú) in the ninth century. The Moche sacrificed large numbers of captive adult warriors at their Temple of the Moon, just a few miles and a few centuries distant from where the Chimú later ruled at Chan Chan.

"With the end of the Moche, the ideas got old, and the rituals lost their potency," Klaus says. "There seems to be something much bigger that the people at Chan Chan got plugged into. Sacrifices are very carefully constructed negotiations and forms of communication with the supernatural. It's the Chimú interacting with the cosmos as they understood it."

THE NEED TO PLACATE THE SPIRITS and stop the rain may have been urgent, but the mass sacrifice itself appears to have been carefully orchestrated. The young llamas—another important resource, culled from state-owned herds—seem to have been specially selected for the event.

Nicolas Goepfert, an expert on camelids at France's National Center for Scientific Research, analyzed the well-preserved coats of the four-legged victims. He determined that the Chimú likely chose particular animals to sacrifice based on their age and color. Dark brown llamas often were interred together with light brown llamas, for example, while no white or black animals were sacrificed.

"We know from the Spanish chronicles that the Inca had a color code for sacrificial llamas," Goepfert explains. "Maybe the Chimú selected them that way as well."

How the children were chosen for their terrible fate remains a mystery. Scientific studies show that those killed at Huanchaquito were both boys and girls, all of whom appear to have been well cared for, with little sign of malnutrition or disease. Isotopic analysis of their teeth suggests that they came from many regions of the sprawling Chimú Empire. The backs of

some of the children's skulls are unnaturally elongated, evidence of a deliberate cranial modification that was practiced only in the remote highlands.

But many questions remain unanswered. Did the children come from elite families or poor ones? Without burial goods, it's impossible to know. How many families lost children in the sacrifice? Were they given up willingly in the face of impending disaster, or let go under compulsion? For now, archaeologists have no answers. But telltale signs and forensic clues are helping them reconstruct the sequence of events.

The pattern of footprints and tracks preserved in the dried mud indicates that there was a formal procession to the sacrifice site. The prints of small bare feet, as well as those of four-legged animals being dragged against their will, make Prieto and Verano think the victims were led alive to their graves, where they were killed. A lack of insects in the remains means the children were carefully wrapped in shrouds and promptly buried alongside the llamas.

That dreadful task may have fallen to two adult women who were killed by blows to the head and buried among the children on the northern side of the site. Nearby were the remains of an adult male, lying on his back under a pile of rocks. His unusually robust build leads the archaeologists to wonder if he might have been the executioner.

Did the costly offering bring relief from the flooding rains? It's impossible to know, but the disturbing event may be a window into the last, desperate years of a dying empire.

"Here you are when you have the most to lose, and you're giving the most," Baxter says. "It speaks volumes about where the Chimú were at this moment and in this place."

Within decades, Inca warriors would arrive at the walls of Chan Chan and depose the Chimú.

MONTHS AFTER wrapping up the excavation at Huanchaquito, Prieto sends word that he has uncovered more sacrificed children and llamas at a location known as Pampa la Cruz. The new site is another empty lot on a high hill, only this one is crowned by a large wooden crucifix, hence its name. The cross was erected more than a century ago by a grateful fisherman who survived near drowning.

A bit farther south along the coast, a new monument built to honor the sacrificial victims of Huanchaquito features a statue of a young boy and a llama surrounded by freshly planted palm trees, one for each human victim. The crest of Pampa la Cruz offers an unobstructed view west to the sea, and when I visit during the Peruvian winter, a few daring surfers are braving the cold waters. By now Prieto has uncovered the remains of another 132 Chimú children, most executed with the familiar horizontal incision across the chest and buried in simple shrouds. His running tally of victims found at the two sites now stands at 269 children, three adults, and 466 llamas.

But what's throwing Prieto for a loop are nine burials clustered at the top of the hill and dug into the ruins of an earlier Moche-era shrine facing the sea.

These graves also hold Chimú children, but they were buried in robes and elaborate headdresses adorned with parrot feathers and carved wooden ornaments. None of the nine victims bear the usual cut marks to the chest, but the skull of one was severely damaged by what must have been a lethal blow to the head.

During the week that I'm at the site, Prieto unearths an enormous copper knife with a rattle on one end that's unlike anything previously discovered by any archaeologist. "My god, what is this?" he blurts out. Could it be the very knife used to kill the children buried here? The possibility is both thrilling and appalling.

Prieto is still struggling to understand the motivation and logic behind the mass killings. But one afternoon as he breaks for lunch, he shares an old story that casts a more charitable light on the Chimú. The colonial chronicles describe an event following the Inca and Spanish conquests in which Don Antonio Jaguar, the leader of the now beleaguered Chimú, escorts his new Spanish overlords to a cache of priceless treasure.

The legend in Huanchaco, Prieto says, is that Don Antonio pointed them to the *peje chico*—the lesser treasure—and that the *peje grande* has yet to be discovered.

"I'd like to think that the children are the *peje grande,* that they were what was most precious to the Chimú," Prieto says thoughtfully, pushing rice around his plate with a fork. "Their lives must have been worth more than gold." □

Archaeology editor **Kristin Romey** writes about new discoveries and ancient cultures. **Robert Clark** has photographed more than 40 feature stories for *National Geographic*.



PART 1

Under this salt flat in Bolivia
is one of the largest deposits of lithium,
the key to powering cell phones,
electric cars, and other tech creations.
All that lithium is inspiring big dreams—
and big concerns.

PAGE 80

HOW WE'RE **FUELING** THE FUTURE

 PHOTOS: CÉDRIC GERBEHAYE (LEFT); LAURA MORTON (RIGHT)



AND CHASING

BIG IDEAS

IN SILICON VALLEY

PART 2

Silicon Valley is still driven by innovation and the search for the next game changer, but it's sobering up to the downsides of the world it created.

PAGE 104

While the indigenous Aymara population harvests and sells salt crusted on the surface of the Salar de Uyuni salt flat, the much more lucrative lithium is dissolved in brine found deep underground.

FUELING BIG IDEAS | PART 1

AS DEMAND SOARS FOR POWERFUL BATTERIES, BOLIVIA DREAMS OF STRIKING IT RICH BY EXTRACTING LITHIUM FROM ITS HUGE SALT FLAT. WHETHER MANY BOLIVIANS WILL BENEFIT IS UNCLEAR.

THE RUSH FOR WHITE GOLD

BY **ROBERT DRAPER**

PHOTOGRAPHS BY **CÉDRIC GERBEHAYE**

Evaporation pools carved out of the Salar de Uyuni create a colorful mosaic at the Llipi lithium pilot plant. The facility began making lithium carbonate in 2013. Lithium-rich brine is pumped from as far as 65 feet beneath the surface into pools. Eventually, the plant will have 200 of them.





At a plant in Brussels, Belgium, a worker looks over the lithium-ion battery that will power the Audi e-tron, an electric SUV. The liquid-cooled battery is made up of separate modules integrated into the floor of the car. Rising electric-vehicle sales have spurred a significant increase in lithium extraction.

One early Saturday morning in La Paz, Álvaro García Linera, the vice president of Bolivia, greets me in the spacious salon outside his office overlooking Plaza Murillo. The debonair, silver-haired 56-year-old politician is known in his country as a committed Marxist ideologue. But today he presents himself as a capitalist pitchman.

The pitch in question involves lithium. García Linera speaks of his country's natural resource in a simultaneously factual and awestruck way. Lithium, essential to our battery-fueled world, is also the key to Bolivia's future, the vice president assures me. A mere four years hence, he predicts, it will be "the engine of our economy." All Bolivians will benefit, he continues, "taking them out of poverty, guaranteeing their stability in the middle class, and training them in scientific and technological fields so that they become part of the intelligentsia in the global economy."

But as the vice president knows, no pitch about lithium as Bolivia's economic salvation is complete without addressing the source of that lithium: the Salar de Uyuni. The 4,000-square-mile salt flat, one of the country's most magnificent landscapes, will almost certainly be altered—if not irreparably damaged—by mining the resource underneath it.

García Linera thus speaks of it reassuringly, even reverently. Leaning in very close, he asks, "Have you been to the Salar de Uyuni?"

When I reply that I'll be heading there soon, the vice president dispenses with his air of mentholated detachment and seems awash with nostalgia. "When you go to the Salar," he instructs me, "go there one night. Spread a blanket in the center of the Salar. Turn on some music."

He is smiling now but emphatic: "Pink Floyd. Turn on Pink Floyd. And stare up at the sky." The vice president then waves his hand to indicate that the rest would become evident.

THE DAYLONG DRIVE from the world's highest capital city to the world's largest salt flat provides a roadside tour of South America's poorest country. From downtown La Paz, perennially clogged with cars and political demonstrations, the road shoots up to El Alto, the working-class stronghold of Bolivia's second largest indigenous group, the Aymara, migrants from the high plains of the Andes Mountains. Over the next seven hours, the route travels steadily downhill—through villages where effigies of would-be thieves are tied to trees in warning, through the mining city of Oruro—until leveling out, at about 12,000 feet, into a mostly vacant





José Edmundo Arroyo, a construction worker at the lithium pilot plant, finishes his shift. The local indigenous population has so far seen only modest benefits from the plant, which has primarily hired its skilled workers from La Paz or Potosí.

NGM MAPS


Ingenieros Ltda.

stretch of scrubland occasionally animated by llamas and their lithe cousin, the vicuña. By late afternoon, the pale shimmer of the salt flat yawns across the plain.

I reach the Salar, Spanish for "salt flat," just before sunset. For about a mile I drive along its smooth and firm surface until its middle-of-nowhereness becomes evident. Stepping out of the SUV and into a gnashing chill, I regretfully conclude there will be no blankets spread beneath the stars accompanied by a trippy Pink Floyd soundtrack. Still, the spectacle is hallucinatory: miles of bleached terrain, relentlessly level and divided into vaguely trapezoidal shapes like a mad giant's checkerboard, its starkness perfected by the cloudless blue sky and the mahogany Andean peaks in the distance. Motorcycles and 4x4s scud across the roadless surface, destinations unknown. Here and there solitary beings lurch about as if in a postapocalyptic stupor, gazing into what the Bolivian vice president calls "the infinite table of snowy white."

Somewhere out of sight on infinity's edge, bulldozers are plowing evaporation pools in the Salar—long and geometrically precise, as if to create a grid of enormous swimming pools. The bulldozers will be moving this way—how soon, no one can say with any certainty.

Here is what we do know. First, that underneath the world's biggest salt flat lies another wonder: one of the world's greatest lithium deposits, perhaps 17 percent of the planet's total. Second, that by exploiting its lithium reserves, the government of Bolivia—where 40 percent of the people live in poverty—envisions a pathway out of its cul-de-sac of misfortune. And third, that this pathway slicing through the largely pristine Salar de Uyuni is at the same time wholly uncharted and—to Bolivians living in a country replete with plundered holes and cheated aspirations—suspiciously familiar.

Bolivia today is still shackled to its past. The country's first Aymara president, Evo Morales, who took power in 2006, cited in his most recent inaugural address the "500 years we have suffered" as a result of Spanish colonialism—a brutal reign of enslavement and cultural expungement that nonetheless ended nearly two centuries ago. Geography and bad governance thereafter conspired to thwart its reinvention. Bolivia's economic prospects suffered when it gave up its coastline on the Pacific Ocean in 1905 after losing a war with Chile. While its neighbors Brazil and Argentina slowly grew more prosperous, Bolivia endured decades of military coups and corruption. The two major indigenous populations, the Quechua and Aymara, are still relegated to lower-caste status by the ruling elite of European ancestry.

BY EXPLOITING ITS LITHIUM, BOLIVIA ENVISIONS A PATHWAY OUT OF ITS CUL-DE-SAC OF MISFORTUNE.

In sum, Bolivia has been a country of sagging self-esteem, latent hostilities, and no shared sense of national destiny. Meanwhile its economic history is one of endless boom-and-bust cycles. Though this is common among countries dependent on their natural resources, some Latin American countries, such as Chile, have managed theirs competently. The Bolivian government, by contrast, has frequently signed away its mineral rights to foreign firms in the interest of quick but fleeting profits. As the vice president told me, "Throughout our history, we have not created a culture that combines our raw assets with intelligent thinking. This has produced a country which is rich in natural resources and socially very poor."

BOLIVIA REMAINS, among Latin American nations, curiously indistinct, its history neither iconic nor volatile. The cameo role it played in *Butch Cassidy and the Sundance Kid* could be seen as a metaphor for its semi-anonymity. Bolivia, in that now classic film, was the somnolent final refuge of two American bank robbers. Glammed up by Hollywood, the outlaws symbolize something appreciably less romantic in Bolivia—namely, the remorseless fleecing of its resources by gringos from far wealthier nations.

A bullet-riddled train the duo are said to have robbed is a featured attraction in Pulacayo, once a bustling mining town. Today Pulacayo is a ghost town. The grand residence of the

German mining baron Moritz Hochschild is now a seldom visited museum featuring vintage photographs of the hardships borne by his laborers—many of them women and children. Documents discovered recently revealed that Hochschild helped thousands of Jews leave Nazi Germany and resettle in Bolivia. As Oscar Ballivián Chávez, a Bolivian geologist, dryly observed, "Hochschild was the Schindler of Bolivia—except not to the Bolivians."

Pulacayo's mines were shut down by the government in 1959, throwing the miners out of work. The town's demise was expected to seal the fate of Uyuni, a mining distribution center 12 miles away. But one day in the 1980s, while searching for a tourist destination to rival Lake Titicaca, a La Paz tour operator named Juan Quesada Valda laid his eyes on the Salar.

Until then, the salt flat had been regarded by Bolivians as not much more than a geographical anomaly. According to a local myth, the Salar formed from breast milk and salty tears that flowed from Tunupa, a volcano looming over it, who cried when her two daughters were kidnapped. But while Tunupa and other surrounding mountains are venerated in indigenous lore, "the Salar has never had cultural significance," said Uyuni's mayor, Patricio Mendoza. "People were afraid that if they took a walk on it, they might get lost and die of thirst or their llamas would damage their hooves on the salt."

When Quesada beheld the Salar, he experienced a revelation, said his daughter Lucía: "You can find lakes anywhere. But you cannot find a salt flat like this anywhere else in the world. He knew he could sell this place."

An architect by training, Quesada proceeded to build the first of several hotels made almost entirely out of blocks of salt in Colchani, a village at the eastern edge of the Salar. Adventurous foreigners began to show up to bask in the great pale desert. Weddings, yoga tutorials, and drag races would eventually be staged on it. Today the salt hotels are routinely full, while Uyuni has become a somewhat mangy, pizzeria-filled vacationland bustling with college-age backpackers.

"Maybe 90 percent of our economy is tourism," Mendoza said.

All of which is to say that in Bolivia's long, morose history of economic disappointments, the Salar provides a happy if modest exception.

But now comes Bolivia's future, in the form of lithium.

WHAT GOLD MEANT to earlier eras, and petroleum to the previous century, lithium may eclipse in the coming years. Long used in medication to treat bipolar disorders—and in items as varied as ceramics and nuclear weapons—it has emerged as an essential component for the batteries in computers, cell phones, and other electronic devices.

The global market's annual consumption of lithium was approximately 40,000 metric tons (a metric ton is 2,205 pounds) in 2017, representing a roughly 10 percent increase year by year since 2015. Meanwhile, between 2015 and last year, lithium prices nearly tripled—a clear reflection of how fast the demand has been rising.

That will likely intensify as electric cars become more popular. One version of the Tesla Model S runs on a battery pack with about 140 pounds of lithium compounds, or the equivalent of what's in 10,000 cell phones, according to Goldman Sachs. The investment firm also projects that every time electric-vehicle sales replace a percentage of all vehicles sold, the demand for lithium increases by 70,000 metric tons a year. Given that France and the United Kingdom have already announced that they'll ban the sale of cars running on gas or diesel by 2040, it would seem evident that a country abounding with lithium need never fear poverty.

Though lithium-mining operations exist on every continent except Antarctica, up to three-fourths of the known lithium reserves are in the Altiplano-Puna Plateau, a 1,100-mile-long stretch in the Andes. The salt bed deposits are concentrated in Chile, Argentina, and Bolivia, known as the "Lithium Triangle." Since the 1980s Chile has produced lithium from brine, and its Salar de Atacama is now the preeminent source of the chemical in Latin America. Chile's government has been the most hospitable to foreign investors, and its mining sector, as the world's largest exporter of copper, has extensive experience. Argentina also began extracting lithium from brine in the late 1990s, exploiting its Salar del Hombre Muerto.

Bolivia's lithium reserves match those of Chile's highly productive Salar de Atacama, but until recently, their potential had gone untapped. "In Argentina and Chile, they've always had a culture of public-private partnerships," said Ballivián, who in the 1980s was among the first geologists to study the

Salar's lithium potential. "Here this government doesn't want to accept private investment. There's a hostility to capitalism."

THE ELECTION of Morales was a symbolically potent one for the indigenous Aymara population. But the new president's rhetoric and actions also had the effect of repelling foreign capital. Morales moved quickly to nationalize the petroleum industry and has taken steps to nationalize some mining operations.

Two years after their election, in 2008, Morales and García Linera turned their attention to the lithium reserves in the Salar de Uyuni, as previous administrations had. "The other governments never produced any lithium," García Linera said. "And what they wanted to do was reproduce the whole scheme of a colonial extraction economy. The Bolivian people do not want this. And so we started from scratch."

From the outset, the new government's operating principle was "100% Estatal!" or complete control by the Bolivian state. "We decided," said García Linera, "that we Bolivians are going to occupy the Salar, invent our own lithium extraction method, and then partner with foreign firms that can bring us a global market."

The "100% Estatal!" slogan carried additional meaning when uttered by an Aymara president. It happens that Aymara make up a large part of the population around the Salar. To declare that the salt flat would become the epicenter of Bolivia's economic revolution was to signal that jobs and deliverance from hardship would at long last come to the country's indigenous people.

García Linera audaciously promised that Bolivia's lithium would be "the fuel that will feed the world." By 2030, he vowed to me, the country's economy would be on a par with those of Argentina and Chile. Morales confidently predicted that Bolivia would be producing lithium batteries by 2010 and electric cars by 2015. These estimates would prove to be way off. As Morales and García Linera would come to learn, lithium mining is an expensive and complicated process, requiring significant capital outlays as well as technological sophistication. Going it alone was never an option for a developing country like Bolivia. At the same time, attracting a foreign firm that would willingly cede control to the state would be challenging for any nation, particularly one with nationalizing tendencies.

"You will surely understand, most industries would love to exploit the Salar," García Linera said, insisting, "We're saying no, the Salar must be fully controlled by Bolivian technicians. And so that has generated some tension."



Trusting nonetheless that the promise of the Salar de Uyuni's reserves would surmount any doubts, the Morales administration stated that Bolivia would have a foreign partner to assist in industrial-scale lithium production by 2013. This, too, proved to be a rash prediction. U.S. companies opted out. So did a top Korean firm. Not until 2018 did Bolivia find a partner: ACI Systems Alemania, a German firm that reportedly will invest $1.3 billion in exchange for a 49 percent stake in the venture.

THE MOST DAUNTING hurdle for Bolivia is a scientific one. Producing battery-grade lithium from brine involves separating out sodium chloride, potassium chloride, and magnesium chloride. This last contaminant is particularly expensive to remove. The Salar receives significantly more



LEFT

A soldier keeps a lookout at an observation post that guards the entrance to the lithium pilot project. The road to the left leads to the plant. All drivers must stop and fill out forms at the table before entering the facility.

BELOW

At the pilot plant, a worker checks lithium carbonate to see if it's dry, the final stage before the chemical is packed in sacks for delivery. The state-run facility has about 250 employees, who wear red jumpsuits and live in adjacent prefab houses. Hundreds more work in construction and services at the plant.







Flags left by tourists from around the world flutter in the wind on the Salar. Drawn by its austere beauty, visitors to Bolivia have flocked to the remote region. Tourism has become the economic mainstay of nearby towns, such as Colchani and Uyuni.

POWERING THE TECHNOLOGY OF TODAY

CHARGING AHEAD

Lithium's unique chemical properties—it's the lightest of all metals, heat resistant, and capable of storing substantial amounts of energy in batteries—are fueling a global rush to extract it from hard-rock minerals and brines.

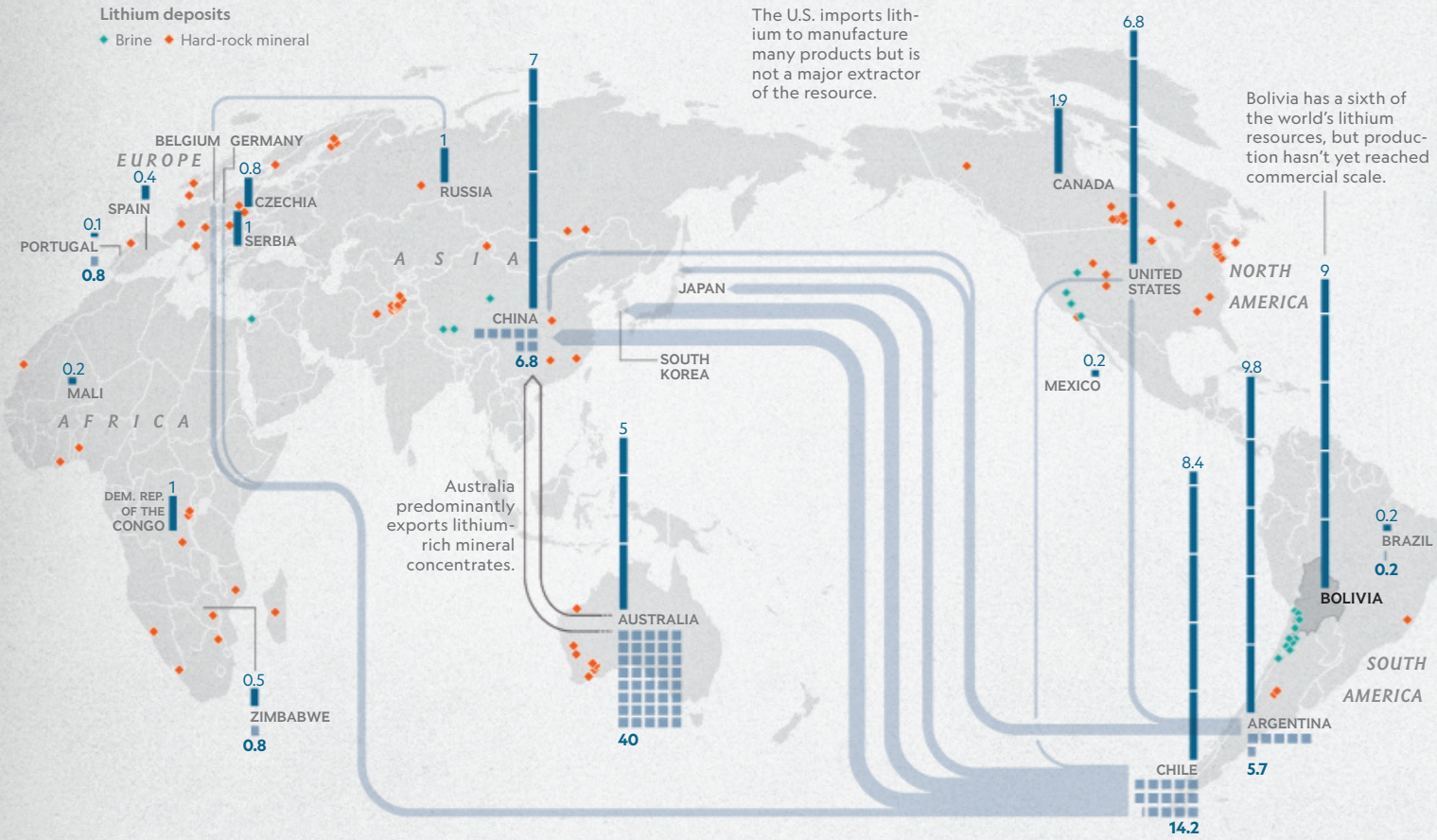
WHERE IT IS AND WHERE IT GOES

Lithium deposits around the world are estimated at 53 million metric tons. Australia currently leads in extraction, but South America is the continent with the greatest amount of this valuable resource.

Lithium Resources
The amount estimated to be in a country, measured in millions of metric tons of lithium content.

Mining Production
How much lithium was extracted in 2017. Each square equals a thousand metric tons.

Carbonate Exports
Lithium is often refined into this key commodity. Exports are shown in thousands of metric tons in 2017.



HOW LITHIUM I

Lithium can be prod
minerals or brines. P
rock is faster but exp
brine is typically che

HARD-ROCK MIN

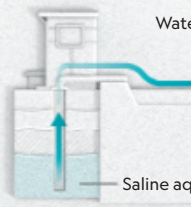
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1 Lithium-bearing
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BRINES

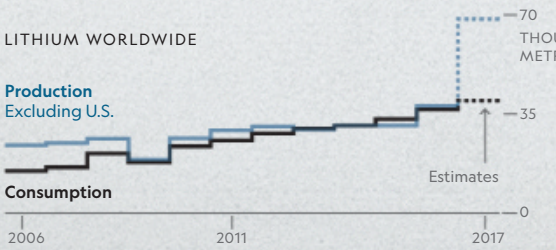
Varying concentration
are found in undergro
tions called continent



1 Wells drilled into
ground aquifers
lithium-bearing b
the surface.

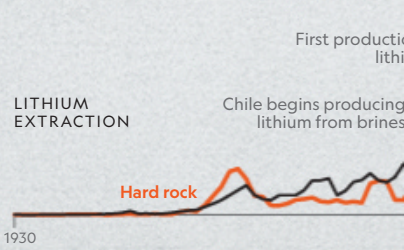
PRODUCTION RAMPS UP

Projecting high demand for lithium compounds, mining production outpaced consumption worldwide in 2017, according to estimates.



BRINE VS. HARD ROCK

Hard-rock minerals were the main source of lithium until the 1990s, when brines, a cheaper source of lithium carbonate, overtook them.



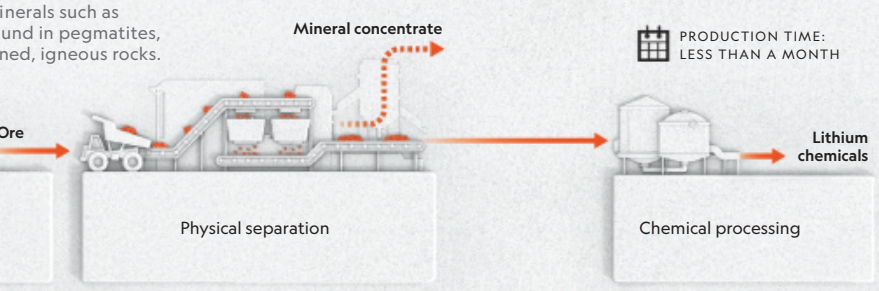
**"UNKNOWN" INCLUDES LITHIUM DATA FROM THE U.S. (1936-1998) AND CHINA (2000-2017) THAT DOESN'T DISCLOSE THE BREAKDOWN BETWEEN HARD-ROCK AND BRINE SOURCES. MEASUREMENTS ARE IN METRIC TONS (A METRIC TON IS 2,205 POUNDS) OF LITHIUM CONTENT. MANUEL CANALES AND MATTHEW W. CHWASTYK, NGM STAFF; AMANDA HOBBS; RONALD PANIAGUA. SOURCES: BRIAN JASKULA, U.S. GEOLOGICAL SURVEY; BRENT A. ELLIOTT AND RAHUL VERMA, BUREAU OF ECONOMIC GEOLOGY, UNIVERSITY OF TEXAS; BRINE VS. HARD ROCK CHART: S.H. MOHR AND OTHERS, *MINERALS* 2012 (UPDATED USING REFERENCES CITED IN ARTICLE); BATTERIES CHART: ADAPTED WITH PERMISSION FROM *MRS BULLETIN* 40 (2015)

IS EXTRACTED

uced from either hard-rock
rocessing lithium from hard
pensive; processing it from
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NERALS

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2 The hard-rock ore is crushed, and the lithium minerals are separated out into a concentrate.

3 Processing, including acid leaching and roasting, yields lithium-based chemicals.

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under-
pump
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2 Brine is moved through a series of surface ponds to concentrate the lithium and remove impurities.

3 Concentrated brine is treated to create lithium chemicals, which are filtered out and dried.

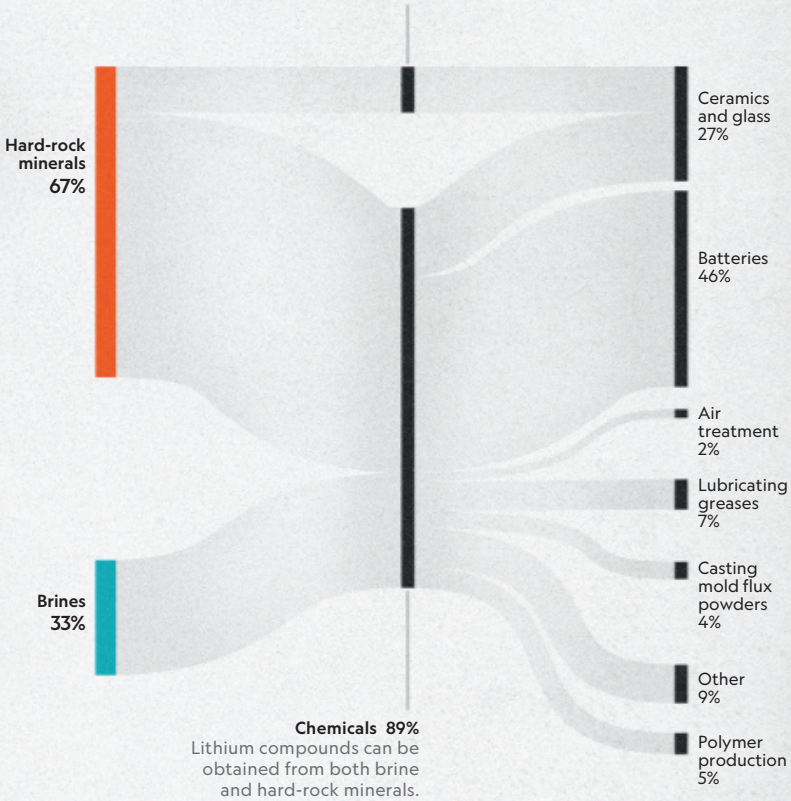
WHAT LITHIUM IS USED FOR

Key to heat-resistant ceramics, glass, and lubricants, it's also increasingly used in high-capacity rechargeable batteries. A growing hybrid and electric-vehicle market is raising demand.

TOTAL PRODUCTION

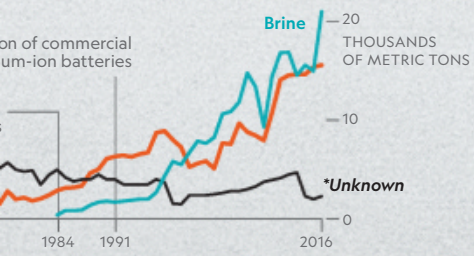
In 2017, lithium produced from hard-rock minerals surpassed brine production, mostly because Australia's output tripled.

Concentrates 11%
A lower, technical grade of lithium can strengthen products like ceramics and glass.



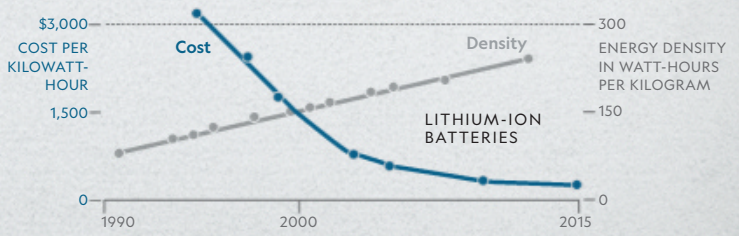
Chemicals 89%
Lithium compounds can be obtained from both brine and hard-rock minerals.

on of commercial
um-ion batteries



BETTER BATTERIES

Advances in engineering and manufacturing have cut costs and improved the energy density of lithium-ion batteries since they were commercially introduced in 1991.




EMPRESA MULTIPLE
"PLAYA BLANCA"
De Teodoro Colque Chozueta y familia
Les desea Feliz Navidad y Prospero Año Nuevo 2015
Colchani y la Empresa
Playa Blanca te espera para
disfrutar del Dakar 2015
HOTEL DE SAL
"PLAYA BLANCA"

Three generations of the Copa family live in four one-room buildings in Chiltaico near the northern edge of the Salar. Like many of the Aymara who live in the region, the family makes money by collecting salt from a small plot, often laboring 12 hours a day in intense sunlight and brisk wind.



Incahuasi, “House of the Inca” in Quechua, was an island when the Salar was a lake in prehistoric times. A remnant of a volcano, it’s covered in cacti, some towering 40 feet, and fossilized algae. Extracting lithium from under the salt flat is certain to alter the spectacular landscape.

rain than its counterparts in the lower altitudes of Argentina and Chile, which can slow the evaporation process. Its lithium deposits also have a higher magnesium content. "While the ratio of magnesium in Chile is 5 to 1, in Uyuni it's 21 to 1. Four times the concentration," Bolivian chemical engineer Miguel Parra said. "So it's a much simpler operation for them. For us, separating magnesium from lithium is the biggest challenge."

I met Parra one morning at Bolivia's Llipi lithium pilot plant, situated on a former llama pasture at the end of a long dirt road. Parra has been the plant's director of operations since shortly after the project began in November 2008. Harsh winds and severe rainfall delayed engineers for years before they succeeded in constructing a 10-mile causeway connecting the plant to the salt flat where lithium is mined.

Aside from a tiny pilot plant that makes batteries in the mining town of Potosí, the multimillion-dollar Llipi plant, which started producing lithium in January 2013, is all the Morales government has to show for its decade-long pursuit of lithium-fueled prosperity. The smallish state-run compound has an all-Bolivian workforce of about 250 employees, most of whom originate not from nearby Aymara villages but from La Paz or Potosí. They wear red jumpsuits and live next to the plant in prefab houses.

Quality control director Victor Ugarte walked me through the fenced and guarded plant. The tour took only a few minutes. The process begins with workers drilling through the hard surface until they reach the brine. The brine is then piped to pools where it's concentrated by evaporation and chemicals are added that cause lithium sulfate to crystallize.

Tankloads of dissolved lithium sulfate are then ferried across the causeway to the three-story plant's uppermost floor. The liquid is first mixed for an hour with lime trucked in from Potosí. This, Ugarte told me, "is the most difficult part—it's how we extract the magnesium so that we can arrive at the purity level we need."

After the magnesium compounds are removed as a gray paste, the remaining liquid is moved to the second floor, where calcium sulfate is filtered out. Chemicals are added to the cooled liquid to create lithium carbonate, which is dried for two hours and loaded into white bags labeled "Carbonato de Litio." About 20 percent is driven 190 miles to the Potosí battery plant. The rest is sold to various companies. "We started off producing about two tons per month," Ugarte told me when I visited. "We're now up to five tons." (Since then, plant officials say, they've reached 30 tons a month.)

IT WOULD SEEM EVIDENT THAT A COUNTRY ABOUNDING WITH LITHIUM NEED NEVER FEAR POVERTY.

I asked the quality control director what the Llipi plant's ultimate production goal was. "Industrial level," he said, "will be 15,000 tons annually." I tried to imagine this unprepossessing little facility somehow, within the next five or so years, ratcheting up to hit that ambitious goal while maintaining 99.5 percent purity, the industry standard for battery-grade lithium.

LOOKING AROUND, other questions come to mind as well. Such as: What does Bolivia intend to do with these imposing gray heaps of magnesium waste? The government points out that magnesium chloride can be used to deice roads, but it stretches credulity to imagine that much being put to such use. For that matter, to separate the magnesium from the lithium, lime is the most economically viable means. The Bolivian government claims that it has a unique processing method that will somehow reduce residual lime waste. But just how much is speculative. According to Bolivian geologist Juan Benavides, "The environmental impact in Chile and Argentina is low. But we're not able to extrapolate, really, because the magnesium content in Bolivian lithium is very high. All we know is that lime is going to be used in greater quantities and that the lithium regulations and laws in Argentina and Chile are more stringent than in Bolivia."

"We're very proud of the preventive measures we've taken to reduce any impact," García Linera told me. "They've cost us a lot of money, in fact."

But it's nearly impossible to assess how an industrialized version of its lithium facility will change the Salar de Uyuni. Among the greatest

concerns is how much water will be required to extract the lithium. Two rivers, the Río Colorado and the Río Grande de Lípez, flow into the salt flat. The former is thin enough to be a creek; the latter, shallow enough to wade across. Both are crucial to the local growers of quinoa, of which Bolivia is the second largest supplier, after Peru. Though the Bolivian government insists that 90 percent of the water it uses will come from salt water rather than underground aquifers, some experts are skeptical that the groundwater supply will be unaffected. "Year after year, the water is going to be the major resource that is needed," Ballivián said. "They'll need vast quantities, more than any other mine in Bolivia."

And finally, there's the still mostly unspoiled surface of the Salar itself. Though revered by human visitors for its seemingly boundless austerity—disrupted only infrequently by patches of cactus-covered, islandlike mountains—it's also a breeding ground for Chilean flamingos. "Our plant is located far away from these sanctuaries," García Linera said, adding, "This demonstrates our commitment to the environment."

Several dozen evaporation pools, some more than 10 football fields long, pock the salt flat, far from where a visitor might encamp some starry evening with a blanket and a cell phone blaring Pink Floyd. But these obscure indentations are meant to accommodate what is now a mere fraction of Bolivia's intended annual exploitation of the Salar. Furthermore, as a vice minister of energy, Luís Alberto Echazú Alvarado, indicated to me, "Our vision is this is a long-term project. So you have to mix poor and rich brine so as to exploit the whole Salar."

"So the government will always drill throughout other parts?" I asked.

"Right, right," Echazú said, nodding vigorously. "Always."

AS I TRAVELED to the dusty villages abutting the Salar de Uyuni—Colchani, Tahua, Chiltaico, Llica—occasional signs of support for Morales would materialize on public walls: "Evo Sí!" But on the subject of Morales's lithium brainchild, residents responded with a weary skepticism, sometimes tinged with worry.

Many Aymara in the region work as *saleros,* harvesting salt and selling it to processing plants. A salt farmer named Hugo Flores, sitting beside his half-rusted pickup truck, told me, "We've received no information from the government. We don't even know what lithium is, what its benefits are, what its effects are." More pointedly, a councilwoman in Tahua named Cipriana Callpa Díaz said, "No one in this municipality is working on the lithium project. We thought there'd be work for our people here, with good salaries. It's very disappointing." When I relayed this sentiment to Parra, the Llipi plant director shrugged helplessly and acknowledged that there were few jobs for unskilled workers in lithium processing. "Children are advised to go to universities and come back with degrees," he said.

Perhaps the most vehement dissatisfaction was expressed by Ricardo Aguirre Ticona, who is the council president of Llica—the capital of Daniel Campos Province. Almost the entire Salar lies within the province.

"We understand that once the plant is fully up and running, it will be a multimillion-dollar business," he said one afternoon in his cluttered office. "The skepticism is whether we'll get any of that. Those who should benefit first are the ones where the production is taking place… And it's not just cash benefits. There should be a faculty of chemical science established here, or scholarships, so young people can have a future. For three years we've been asking for this. Now we're asking for an audience with the president. He hasn't been here for a long time."

Aguirre measured his next words carefully. "The Bolivian population is patient," he said. "But if necessary, it will take measures to be heard."

In Bolivia, his statement needs no elaboration. In 1946, the population decided it had no more patience for President Gualberto Villarroel, who initiated labor reforms but enforced repressive measures when miners made more demands. Angry Bolivians raided Villarroel's palace and killed him. They strung his body to a lamppost in Plaza Murillo—the square adjacent to the palace where I'd met with the vice president to discuss the latest plan to reform Bolivia's economy. I thought about that dark reminder from the past as I left Llica in the SUV and barreled once again through the colorless daydream of the Salar, an illusion of simplicity that could go on forever but in fact does not. □

Robert Draper is a contributing writer who lives in Washington, D.C. **Cédric Gerbehaye** is a freelance photographer based in Brussels. This is his second magazine assignment for National Geographic.

SILICON VALLEY GROWS UP



(SORT OF).

IT'S STILL A LAND OF OPPORTUNITY, BUT NOW IT'S CONFRONTING THE HUMAN COST OF ITS SUCCESS. THE NEW BUZZWORDS: RESPONSIBILITY AND EMPATHY.

BY **MICHELLE QUINN** PHOTOGRAPHS BY **LAURA MORTON**



Teslas jockey for one of 12 electric-vehicle charging stations in the parking lot. A sea of mostly men gathers in the lobby of the Computer History Museum, some giving each other quick hugs. "How's my investment going?" one shouts to another across the room. A bell chimes, and it begins to feel like church. The boisterous crowd files quickly into the auditorium and becomes quiet. The doors close. Demo Day is about to begin.

Over the next two days, entrepreneurs from 132 start-ups pitch well-rehearsed two-minute spiels about how they are going to change the world. Turns out, there are countless ways to do that. Radar sensors on bedroom ceilings in nursing homes. Drones that check utility lines. Machine learning for cargo shippers. A laundry-detergent subscription service aimed at men.

On average there's a future billion-dollar company in every group, Michael Seibel, CEO and partner at Y Combinator, tells the Silicon Valley investors. "Your job is to figure out which one it is," he says. His firm helps entrepreneurs develop their ideas.

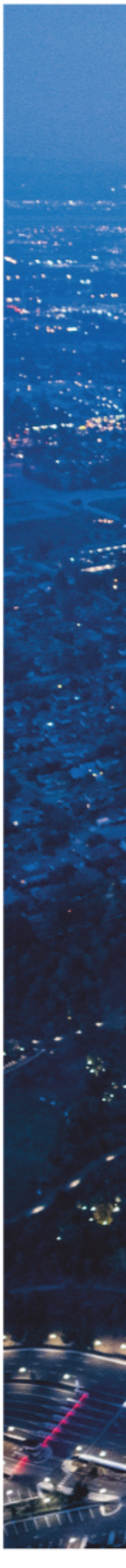
First up is Public Recreation, which offers group workouts in parking lots and other open spaces to exercisers who pay a subscription. "Our secret sauce is, we don't pay rent," says one of the founders.

Is that a big market, I wonder as everyone claps. And what about rain, snow, insects, and high-pollen-count days? But we're on to the next big idea—container optimization for ports using predictive algorithms. The hush in the room is respectful.

During my years as a reporter writing about Silicon Valley, I've learned to stifle the urge to guffaw at business ideas. Billions have been made on start-ups I dismissed as toys, solving problems I didn't know people had. Maybe if Plan A doesn't work, Public Recreation can switch to Plan B, like Justin.tv, which started by live-streaming the antics of one person, Justin, then anyone, and then turned into Twitch Interactive, which enables one to watch others play online games. In 2014, Amazon bought it for $970 million.

Silicon Valley is a place that is always "fleeing into the future," says Paul Saffo, a longtime Silicon Valley observer. The entrepreneurs pitching on this Demo Day paint a picture of lives made better by artificial intelligence, augmented reality, robots, drones, and sensors everywhere.

Silicon Valley's optimism and the pragmatic dreamers who keep it going



The first publicly traded U.S. company worth a trillion dollars, Apple has set the pace for innovation in Silicon Valley and continues to expand its influence. Its new headquarters building in Cupertino, which opened in 2017, is known as the "spaceship." About 12,000 employees work there, less than half of Apple's Bay Area staff. Recently Apple also has been a critic of Silicon Valley, advocating for customer privacy with jabs at other tech companies.
CAMERON DAVIDSON

PREVIOUS PHOTO

Fueled by snacks, energy drinks, and diet soda, students from Singapore's Nanyang Technological University develop ideas for an augmented reality app for photographers during a hackathon in Santa Clara.

VALLEY OF THE BOOM

Take a ride on the roller coaster that was the 1990s dot-com boom and crash by tuning in to National Geographic's six-part miniseries *Valley of the Boom,* which premieres January 13 at 9/8c.



MINDS, MONEY, AND MACHINES

EVOLUTION OF A REVOLUTION

It's been 80 years since a start-up called H
The networks fueling the subsequent ris
necting our ever smaller devices but also t

ANALOG TO WIRELESS

Electrical signals of ones and zeros move faster and faster over expanding networks.

TRANSISTORS TO SMARTPHONES

From room-size computers to pocket-size smartphones, our technology is getting smaller and more powerful.

PROFESSORS TO CODERS

From academics such as Frederick Terman—who first encouraged students to start electronics firms—to today's CEOs in hoodies, Silicon Valley's leaders have been networking.

MILITARY MONEY TO VENTURE CAPITAL

Tech dollars flow after electronics companies such as Hewlett-Packard win military contracts over East Coast rivals in 1943.

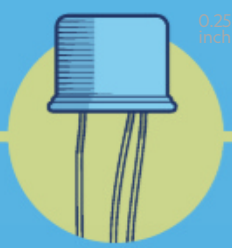
1950

Computers "talk" over phone lines through modems originally developed for transmitting Air Force radar signals.



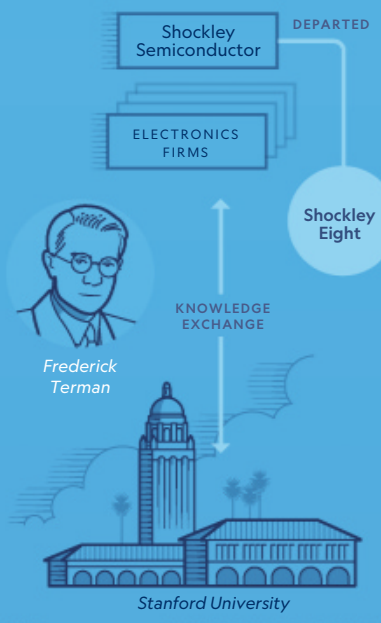
TELEPHONE

Newly invented transistors replace vacuum tubes and are the first step to integrated circuits—arrays of densely packed transistors.



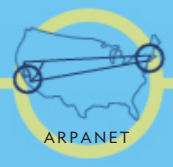
TRANSISTOR

Shockley Semiconductor Laboratory brings transistor technology to Silicon Valley. A few years later, eight engineers leave to form Fairchild Semiconductor.



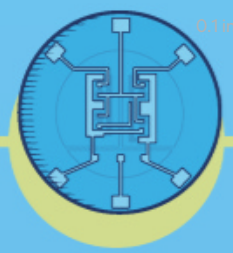
1960

Stanford Research Institute is one of the first two nodes of the U.S. government's ARPANET, later known as the internet.



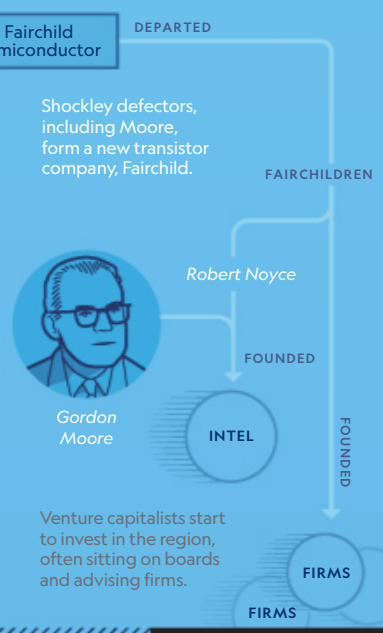
ARPANET

Texas Instruments' Jack Kilby and Fairchild Semiconductor's Robert Noyce invent the integrated circuit, or "chip."



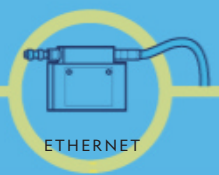
INTEGRATED CIRCUIT

Fairchild Semiconductor is an incubator for talent that leads to more than 120 spin-offs, building a family tree of risktakers and company founders.



1970

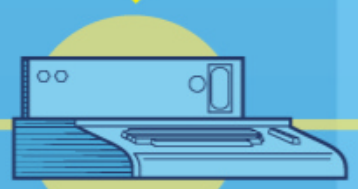
The Ethernet standard is developed at Xerox's PARC, connecting computers and printers over local-area networks.



ETHERNET

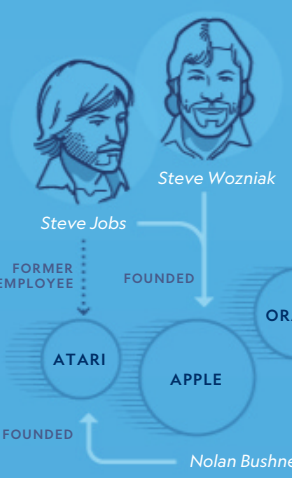
Apple-1 is one of the first personal computers; video gaming begins.

Local-area networks



APPLE-1

Friends Jobs and Wozniak attend meetings of the Homebrew Computer Club and start to work together on what will become the Apple-1.



Xerox's PARC lab creates a graphical user interface, with windows and menus, that inspires the Apple Macintosh.



Xerox's PARC

MILITARY

VENTURE CAPITAL

IPO

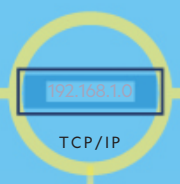
ewlett-Packard was dreamed up in a Palo Alto garage.
e of Silicon Valley have included not just those con-
the networks of innovators who've made it all happen.

43% OF U.S. VENTURE CAPITAL INTO THE INTERNET GOES TO SILICON VALLEY

50b DEVICES WILL BE CONNECTED TO THE INTERNET BY 2020

80

The TCP/IP standard states how networks should talk to each other, laying a foundation for the internet and World Wide Web.



IBM PC, Apple Macintosh, and Sun-1 workstations become common.

Connecting networks



MOUSE, GRAPHICAL USER INTERFACE

Doug Engelbart of Stanford Research Institute develops an "X-Y position indicator" that will later be known as the "mouse." The technology is leased to Apple.



The first cyber-criminal hacks into Lawrence Berkeley National Laboratory.

CISCO

ADOBE

1990

WWW "browsing" software is available from several sources. The most popular early browser is Netscape Navigator.



The World Wide Web (WWW) is born.

First public access to the internet



WEBSITES

Start-ups take advantage of their proximity to Silicon Valley's venture capital, law, and public relations firms, further raising their profiles in the national consciousness.



Larry Page *Sergey Brin*

Stanford students Larry Page and Sergey Brin invent Google in their dorm rooms.

FOUNDED

EBAY

NETSCAPE

GOOGLE

PAYPAL

The first private companies attempt to capitalize on the World Wide Web.

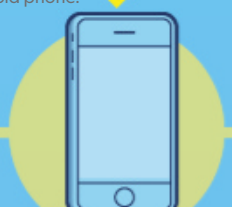
2000

Each internet-connected device needs an address; the IPv6 system is created to expand address space as it runs low.



Apple unveils the iPod and iPhone; Google creates the Android phone.

Seamless connection



SMARTPHONES

Mark Zuckerberg and Jack Dorsey create technology that shapes our lives and connects us but that also raises privacy and other concerns.



Mark Zuckerberg

FOUNDED

FACEBOOK

UBER

WHATSAPP

TESLA

TWITTER



Jack Dorsey

FOUNDED

23ANDME

Silicon Valley's leading internet companies are publicly traded on the stock market.

2010

The IPv6 system can cover up to 340 trillion addresses. 4G mobile networks increase their reach, allowing an explosion of mobile-device use.



INTERNET OF THINGS

The Internet of Things concept refers to a network of devices connected to the internet and each other, such as your phone and thermostat.



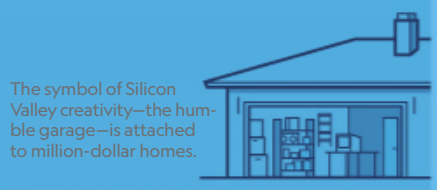
Scientists are able to store massive amounts of data on synthetic DNA.



Anne Wojcicki

Anne Wojcicki's 23andMe decodes family history; pools of genetic data help advance medicine.

FOUNDED



The symbol of Silicon Valley creativity—the humble garage—is attached to million-dollar homes.

MANUEL CANALES, NGM STAFF. PATRICIA HEALY. ART: MATTHEW TWOMBLY
SOURCES: MARTIN KENNEY, UNIVERSITY OF CALIFORNIA, DAVIS; DAG SPICER, COMPUTER HISTORY MUSEUM; PWC/CB INSIGHTS

Silicon Valley can fool you: It looks egalitarian, open, and casual, with CEOs in hoodies and venture capitalists in bike shorts. But it's serious about its ambition.









HOW SILICON VALLEY WORKS









TOP ROW, FROM LEFT

New Facebook employee Nicole Voulgaropoulos and her mom, Sheryl Green-Voulgaropoulos, pose in front of Facebook's thumbs-up sign in Menlo Park as Mel Voulgaropoulos, her father, photographs them. Computer science student and frequent hacker Danny Hyun Cho (left) takes a Ping-Pong break at AT&T's Entertainment Hackathon last July. An Airstream trailer doubles as a meeting room in the open-office environment at Airbnb's headquarters in San Francisco.

BOTTOM ROW, FROM LEFT

Australian Tristan Matthias spent a week working and living in the Startup Embassy (now closed), a shared "hacker house" in Palo Alto. Maggie Ford, engineering director of the Stanford Solar Car Project, demos a solar car with her team at a September activities fair at Stanford University. In San Francisco, Suzanna Rush, Lydia Lewis, and Jonny Price (left to right) have a staff meeting in a room that also functions as a bedroom for the CEO of the equity crowdfunding platform Wefunder.





Joshua Carpentier, an employee at a start-up named Essential, works in the playground area at the offices of Playground Global in Palo Alto. Playground funds and supports start-ups developing new technology, with a focus on artificial intelligence. Carpentier says, "I always made a point of going down the slide once a day. It was a good reminder to have fun and never take what you do too seriously." Carpentier was laid off last October, when Essential cut 30 percent of its staff.

have long fascinated me. But recently there's been a sobering-up of sorts.

Responsibility and empathy are the new buzzwords. Silicon Valley knows it is being held accountable for everything: the demographics of its workforce, the industries upended and the pain caused by technology, the hate spread faster because of its social networks, and even the effects of innovation on people here. Even some workers with six-figure incomes have trouble affording housing. And around the world in places such as Bolivia, mining the lithium needed to power the devices Silicon Valley invents is raising concerns about exploitation and the environment (see story, page 44).

Technology rules the future, but there's also a grudging acknowledgment that sometimes in the pursuit of making things better and more efficient, you may be hurting people along the way.

"We are surrounded by people who are dreaming big," says Anne Wojcicki, co-founder and CEO of 23andMe, the personal-genomics and biotechnology firm. "The reality of Silicon Valley is on the right side of history—whether we like it or not, the world has changed. But those transitions can definitely be hard," she says. "I think we have a responsibility to all those places that are being impacted."

BILLIONS HAVE BEEN MADE ON START-UPS I DISMISSED AS TOYS, SOLVING PROBLEMS I DIDN'T KNOW PEOPLE HAD.

EVERYONE HAS A DREAM

"Where is Silicon Valley?" out-of-towners ask me when they visit. There's no capital city or ground zero. There's no Hollywood-like sign in the hills announcing Tech Town! With low mountain ranges to the east and west, Silicon Valley is a horseshoe-shaped flatland of offices and neighborhoods. Dazzling at the center are the waters of San Francisco Bay, indifferent to the roar of the traffic clogging the roads or the latest breakthrough from Elon Musk, the chief executive of Tesla and SpaceX. I point visitors to the Facebook thumbs-up "like" sign, next to the company's expanding headquarters. Facebook doesn't offer tours, nor do most tech companies.

Of course, that "like" sign might not make everyone happy. We know Facebook's data policies failed to protect users after a researcher sold personal information that was later used to target us with political ads, and Russian operatives stoked political hostilities in the United States by using Facebook as a propaganda arm. Tech's epicenter might be the site in Mountain View where one of the inventors of the transistor started a company, a place that Apple co-founder Steve Wozniak visited just to touch the building and see the historical marker there. It can be found in a home on a cul-de-sac in Los Altos, where an Indian-born software engineer tucks her kids into bed and gets back online to work on her start-up. Or it can be found in a recreational vehicle with three flat tires parked near Stanford University, where Jim, a Marine Corps veteran and handyman, lives with his dog, Smokey, and bathes each day with hand wipes.

It's a much different place from what it was in 1982, when *National Geographic* wrote about Silicon Valley's "freewheeling egalitarianism that has replaced the rural pace" and said, "this dynamic growth happens behind a deceptively sedate facade…a monotone sprawl of low, rectangular buildings on which corporate nameplates display fusions of high-technology words that give few clues as to what goes on inside."

Along winding roads in the surrounding hills where deer feed, one can imagine the people here living at a rural pace. Once the home of apricot and plum orchards, the valley has just last year seen the shuttering of a landmark cherry stand and the closure of Orchard Supply Hardware, which was founded in San Jose during the Great Depression. Yet Silicon Valley can fool you: It looks egalitarian, open, and casual, with CEOs in hoodies and venture capitalists in bike shorts, and it is often whimsical, with workplaces that require people to remove shoes or allow them to bring their dogs.

But it's serious about its ambition. "People are more interested in your start-up than your actual name," complains Tristan Matthias, 24, an Australian visitor.

The seeds of Silicon Valley's appeal today began in the early 1990s. As a reporter arriving

then, I thought the place felt kind of dead. The decline of the defense industry at the end of the Cold War and a downturn in the economy resulted in layoffs throughout California. The hot categories were desktop publishing, multimedia CD-ROMs, and video games.

Even the great rebel—Apple—seemed to be in decline. Steve Jobs was gone, having left in 1985 after a dispute with the CEO and board; his triumphant return to the company he founded would happen more than a decade later.

An idea was spreading in the mid-1990s: If people could be connected through computers, lives would change. I visited a school that was trying out connected computers with its students so teachers could send messages to parents through a dial-up modem. America Online appeared with its idea of a digital mall you could visit and order flowers from. It was clunky and hard to use, but something big was percolating.

There was a party happening to the north, in Seattle. Microsoft was making computers useful and becoming rich. In August 1995, Microsoft seemed like the winner in a winner-takes-all tech contest. Its executives danced at midnight outside electronics stores, celebrating the launch of the operating system Windows 95. Meanwhile a bomb of sorts was going off in Silicon Valley.

Netscape, which made "browser" software that allowed users to move around the internet, went public less than a year after its signature product was released. Although Netscape was an unproven company with pages of risks outlined for investors, its stock price closed at $58.25 on opening day, giving the company an instant market value of $2.9 billion.

Netscape's initial public offering (IPO) was the beginning of what came to be known as the dot-com boom, which saw the creation of great lasting companies such as Amazon and Yahoo!—as well as firms that cratered, such as Webvan and Pets.com.

Excitement over what could be done on the internet—sell makeup, rent trucks, find dates, and more—fueled a speculative stock market. In 1999 more than 400 companies, most of them tech related, went public.

Then the market crashed in 2000. More than 200,000 jobs were wiped out.

Embarrassment. Suffering. And yet: "All those start-ups were right," Wozniak, Apple's co-founder, told me. "They were all right about what the internet would do for us. It's just that you can't change your ways of life that quickly."

Silicon Valley has its own words that turn failure into something positive. "Iteration" means getting a product on the market without worrying about perfection—the tweaks can come later. "Pivoting" (said without embarrassment) is sharply changing course before the money runs out.

Failure and downturns clear the way for new ideas and new entrants. Google occupies part of what was once the site of Silicon Graphics, Inc., a computer company whose co-founder helped start Netscape. Facebook has updated the old Sun Microsystems campus as it has grown. The attempt to link the internet and television was a bumpy ride. But then YouTube showed up.

The social media era launched. Facebook co-founder Mark Zuckerberg moved to Palo Alto to grow Facebook with its hacker creed "Move Fast and Break Things." In San Francisco a group of friends and co-workers found a way for people to give updates throughout their day in 140 characters, and Twitter was born.

The great churn of Silicon Valley masks what happens to individuals. For many, innovation's great "creative destruction" cycles are not observed from 30,000 feet but are wrenching on a personal level. Jobs lost. Skills made obsolete. Households and families upended.

Apple offered another template: the comeback. With Steve Jobs back in the driver's seat in 1997 after the company bought the other firm he started, NeXT, Apple began a slow recovery. The company released the iPod and then its digital entertainment store, iTunes. The iPhone launched in 2007, delivering on the promise of General Magic's Magic Cap and Apple's Newton more than 10 years earlier. Fast-forward to today, and tech companies are grappling with their dramatic impact on people's lives. Their leaders have been called to Congress to testify about the use of customer data, the ways foreign actors have used these prized technologies to disrupt elections, and potential bias in the algorithms that control what we see.

With the advent of artificial intelligence—computers learning to think like humans—data (with its partner, computational speed) has become the most important resource. The new oil. If computers can "think" one day and make decisions, then what?

After more than 3,000 of Google's employees signed a letter in protest, the company chose to

CRADLE OF INNOVATION AND INEQUALITY

THE HIGH PRICE OF LIVING HIGH TECH

Silicon Valley, nicknamed for its early days of silicon-chip innovation and manufacturing, has grown from a techie outpost around Palo Alto to a sprawling Bay Area region of high-tech industries and ever higher housing prices that's known globally as the ground zero of our digital age. Its universities, innovators, and entrepreneurs have transformed the area into a massive engine of wealth. But the prosperity has not reached all, and as the "valley" grows and continues to transform, it is deeply divided along lines of homeownership, wealth, and opportunity.



RENTERS

Search for affordable housing

Census block group with more **renter-occupied** housing units than owner-occupied housing units

Rental cost as a proportion of median household income (2012–16)

30% or less — 40% or more

A closer look at poverty

Poverty rates in Bay Area regions can be nearly 19 percent, double the official rates, according to the California Poverty Measure, an index that factors in regional differences in housing costs and noncash benefits such as food stamps.

Lower rents but poorer renters

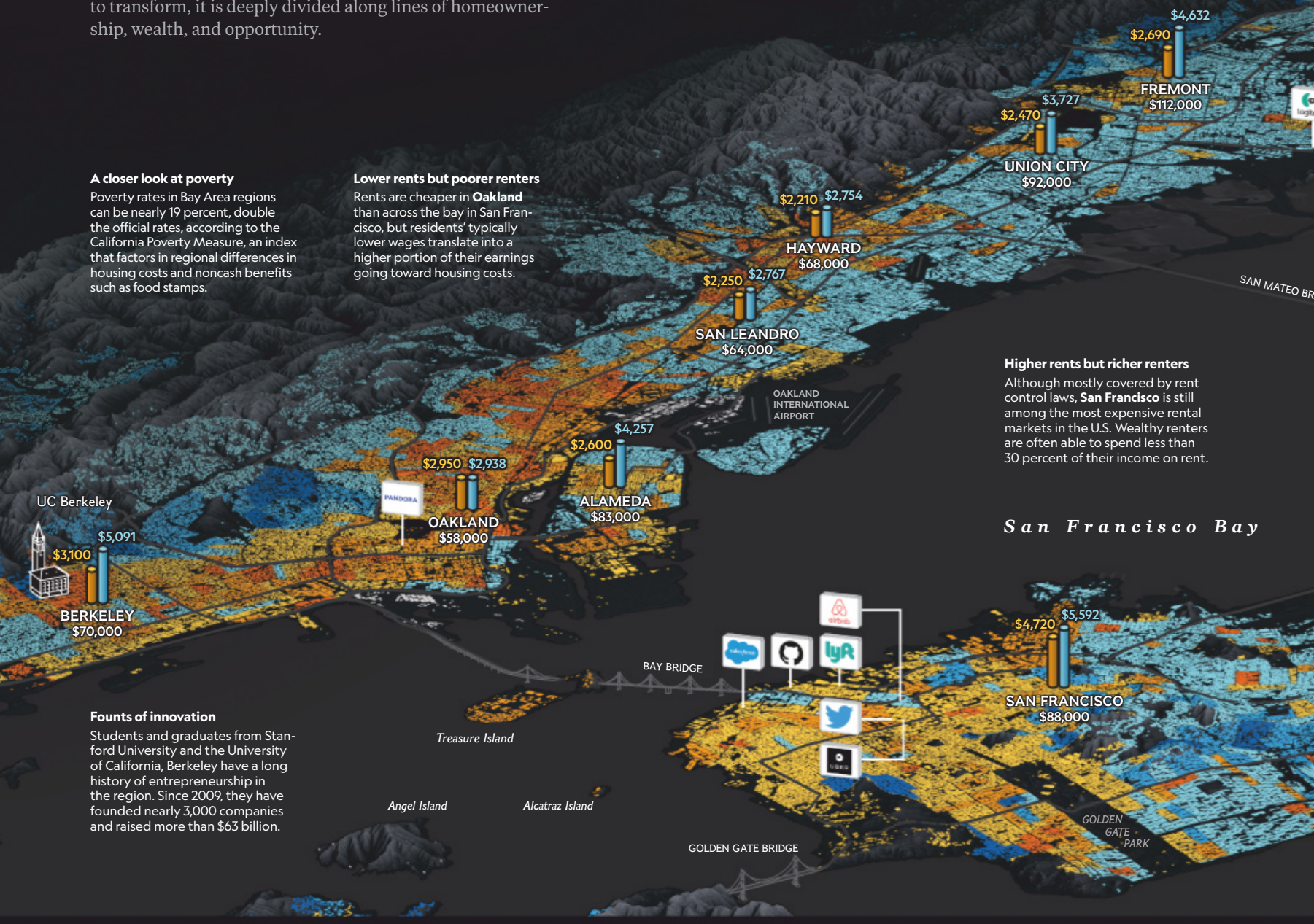
Rents are cheaper in **Oakland** than across the bay in San Francisco, but residents' typically lower wages translate into a higher portion of their earnings going toward housing costs.

Higher rents but richer renters

Although mostly covered by rent control laws, **San Francisco** is still among the most expensive rental markets in the U.S. Wealthy renters are often able to spend less than 30 percent of their income on rent.

Founts of innovation

Students and graduates from Stanford University and the University of California, Berkeley have a long history of entrepreneurship in the region. Since 2009, they have founded nearly 3,000 companies and raised more than $63 billion.



Spending 30 percent of a household's income on rent is the standard threshold for affordability in the United States. In the Bay Area, that figure is closer to 39 percent. Due to barriers to homeownership, such as the need for a large down payment, renters are typically younger and—except in San Francisco—likelier to have lower incomes.

Median rent list price
2-bedroom unit, September 2018

Estimated monthly mortgage cost*
Based on median home sale prices, August 2018

SAN LEANDRO
$2,250 | $2,767
$64,000
Median household income (2012–16)

Just under one-fourth of the region's population can afford to purchase a median-price home, according to the California Association of Realtors. In San Francisco the path to homeownership is even tougher—accessible to only 15 percent of inhabitants. For those who can afford to buy, escalating home values create a surging source of equity.

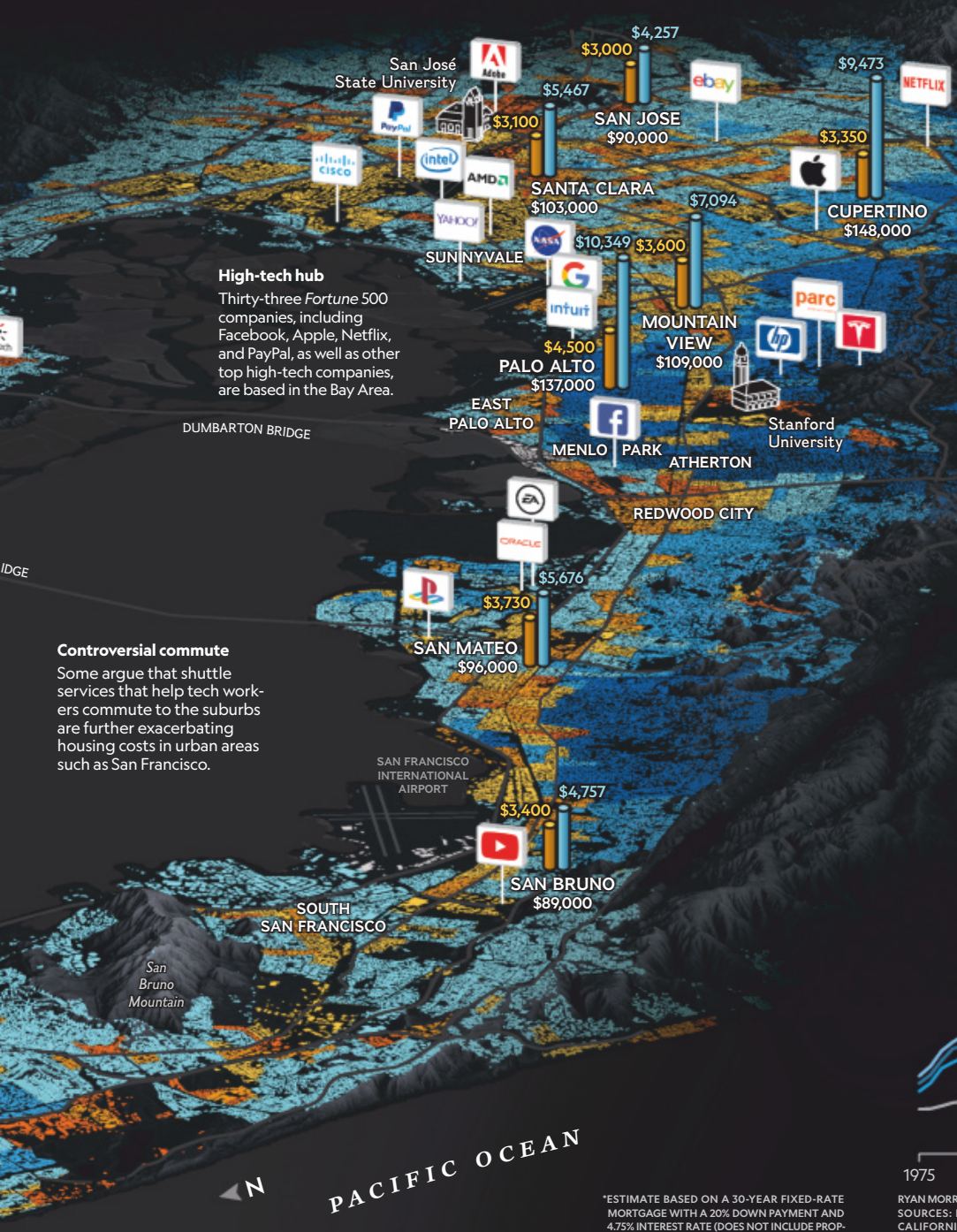
HOMEOWNERS

High price of entry

Census block group with more **owner-occupied** housing units than renter-occupied housing units

Median home value (2012–16)

$1 million or less — $1.5 million or more — No residential housing



High-tech hub
Thirty-three *Fortune* 500 companies, including Facebook, Apple, Netflix, and PayPal, as well as other top high-tech companies, are based in the Bay Area.

Wealthy enclaves
Many of the most expensive homes are nestled among the foothills on the peninsula. Several tech-giant headquarters are a short commute away.

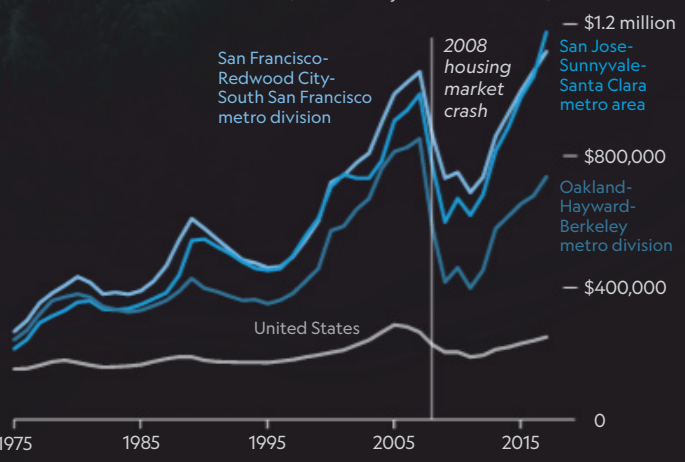
Controversial commute
Some argue that shuttle services that help tech workers commute to the suburbs are further exacerbating housing costs in urban areas such as San Francisco.

Gospels and Acts Codex, Chester Beatty Papyri (P45) Third century A.D.

COUNTING THE COSTS

A typical single-family home costs about $1.3 million in San Francisco and $750,000 in Oakland—prices perhaps within reach for tech workers earning $123,000 annually on average but not for service-industry workers making $30,000. The highest home values of all are in Atherton, with a median approaching $7 million. Compare that with the median cost of a home in the U.S.: $217,000.

Median sale prices of existing single-family homes, 1975–2017 (inflation-adjusted 2017 dollars)



*ESTIMATE BASED ON A 30-YEAR FIXED-RATE MORTGAGE WITH A 20% DOWN PAYMENT AND 4.75% INTEREST RATE (DOES NOT INCLUDE PROPERTY TAXES OR HOME INSURANCE)

RYAN MORRIS, NGM STAFF; PATRICIA HEALY
SOURCES: IPUMS NATIONAL HISTORICAL GEOGRAPHIC INFORMATION SYSTEM, UNIVERSITY OF MINNESOTA; CALIFORNIA ASSOCIATION OF REALTORS; ZILLOW GROUP; BAY AREA COUNCIL ECONOMIC INSTITUTE; BLS; PPIC; U.S. CENSUS BUREAU; MOODY'S ANALYTICS

The young out-of-towners keep coming. After three years, product manager Shriya Nevatia is on her third job. “It sounds bad, but I prefer tiny start-ups,” she says.









BOTTOM LEFT PHOTO: MARY BETH MEEHAN

HOW SILICON VALLEY LIVES









TOP ROW, FROM LEFT

Dressed as a mermaid, Heather Jenkins dances at a morning alcohol- and substance-free party in San Francisco, Daybreaker, designed to energize attendees for the workday. Andrew Kim works at the summer office of DoNotPay—in the same Palo Alto house rented by Facebook co-founder Mark Zuckerberg in 2004. Members of the Violet Society, a program for young women who want to build start-ups, network at a backyard event co-sponsored by Wefunder.

BOTTOM ROW, FROM LEFT

Imelda Valencia spent time living in a trailer parked on a friend's driveway, because her job cleaning houses in Atherton, one of the most expensive U.S. zip codes, pays barely $600 a week. Mykel Hall prepares dinner at his mother Patricia Carter's home in East Palo Alto. The house nearly went into foreclosure last year. Entrepreneur Gideon Nweze, founder of a blockchain start-up for managing digital currencies, uses the massage chair at Node, a blockchain members club in San Francisco.

not extend its contract with a Department of Defense project that uses artificial intelligence to analyze drone images. Then, in November, 20,000 Google employees worldwide walked out to protest the company's handling of sexual harassment and pay-equity issues. Salesforce created an Office of Ethical and Humane Use of Technology following criticism of its contract with U.S. Customs and Border Protection.

I visit John Hennessy, a former president of Stanford University and now chairman at Alphabet, the parent company of Google. He is congenial but not in a relaxed, academic way. The tech industry's current moment of reckoning is spurring deeper questions about Silicon Valley's purpose, he says.

"The tricky thing right now is for companies to figure out how they're going to take responsibility and govern themselves in ways that are seen as aligned with not just the interest of their shareholders but also the interest of society broadly," he says.

THE START-UP LIFE

The young out-of-towners keep coming.

"You sit in a coffee shop and hear a pitch and people talking about crypto and Google, and that's a turnoff for some people. But I like it," says Shriya Nevatia, a product manager from upstate New York who left Boston after graduating from Tufts University.

In three years in Silicon Valley, Nevatia is on her third job. "It sounds bad, but I prefer tiny start-ups," she says.

In a leafy Palo Alto neighborhood, Joshua Browder sits poolside at the home where Facebook's Zuckerberg stayed in the summer of 2004 as the social media site was taking off. Inside the house, Browder's colleagues work at a dining room table on his company's app—DoNotPay—which is like a robot lawyer fighting parking tickets and finding price loopholes for airline and hotel bookings. The condition of the kitchen—a pan caked with tomato sauce—is just part of the gestalt of the hacker life: living, working, eating, and sleeping in one place as they race to launch the product. The past and present are entwined in tech legends—people who live, work, and invest in tech. Wozniak is a sought-after speaker, getting well over a thousand invitations a year. Part of his appeal is that he's the "other Steve" in Silicon Valley's favorite origin story, the creation of Apple. Woz, as he is known, may be a genius,

'THEY ARE BUILDING ONE-MILLION-DOLLAR HOMES RIGHT NEXT TO HOMELESS SHELTERS.'

—PASTOR PAUL BAINS

but he sees himself as a regular guy. He retells one of the most famous stories about himself: Around the time of the company's IPO in 1980, he sold some of his Apple stock at pre-IPO prices to about 80 employees.

"I have a lot of concerns about the distribution of wealth," he says.

THE 'BRO CULTURE' ENDURES

This is Immigrant Valley today as much as Silicon Valley. The influx of foreign-born people is helping to offset an outflow to elsewhere in the U.S. In some fields, such as computers and mathematics, foreign-born workers now make up more than 60 percent of the workforce. The figure is even higher for women in those fields—78 percent are foreign-born. Indians, Chinese, and Vietnamese are the main groups of foreigners in the region's tech industry, but people come from dozens more countries: There were 42 people from Zimbabwe working in tech in 2015 and 106 from Cuba.

The international nature of Silicon Valley means companies, even small ones, have become a jumble of cultures and languages. But it also highlights who isn't making it into the Silicon Valley dream. On average African Americans and Latinos combined make up just 12 percent of the workforce at major tech firms. Women also are vastly underrepresented in what has been called Silicon Valley's "bro culture": Slightly more than 30 percent of the workforce at Google, Apple, and Facebook is female. A survey released last September found that women make up just 13 percent of start-up founders and hold only 6 percent of founder equity.

But women are also slowly gaining traction. In 2018, women made up 24 percent of technical jobs and 18.5 percent of firms' leadership,

according to a survey of 80 U.S. companies by AnitaB.org, a nonprofit that works to increase women in tech fields.

When it comes to pay, women in tech are offered less than men more than 60 percent of the time for the same role (with an average gap of 4 percent), according to a report by Hired, a job-hiring firm. Major tech companies say they want more diverse teams, but it's hard to change employee demographics quickly.

"I've heard young women say Silicon Valley is bad for women, and they brace themselves for it," says Shriya Nevatia, the product manager, over a cup of tea. She has created a group called the Violet Society to help women and nonbinary people during the first 10 years they are in tech, to help get start-ups going. She's intrigued by the wide networks men have developed during college, through roommates, and in their early careers. Companies, seemingly founded through what seem like chance connections, actually arise from these networks. "We need more women for happenstance," says Nevatia, who wants to bring women together in the same way.

SQUEEZED BY THE BOOM

As out-of-towners continue to pour into Silicon Valley, driving up real estate and rental prices, many people here who aren't part of the tech economy—and some who are—see life becoming more difficult, mostly because of the rising cost of housing.

No place is perhaps more squeezed than East Palo Alto, a city of about 30,000 with formidable neighbors: Facebook is just to the north, and Google is to the south. For the past 50 years, the city largely has been a mixture of African-American and Latino families. Now new families, many white and Asian, are moving in. The median home price has already passed one million dollars—up from around $260,000 in 2011, according to Zillow. One million. That's what passes for affordable housing along the peninsula that stretches from San Francisco to San Jose.

For many longtime residents here who haven't enjoyed the current tech boom, rents have escalated, and buying a home is out of reach. They move out to the edges of the area, driving for hours each day to and from work. Or they move in with family and friends. Or they leave the area altogether. "They are building one-million-dollar homes right next to homeless shelters," says Pastor Paul Bains, who with his wife, Cheryl, runs a human-services nonprofit in East Palo Alto.

Patricia Carter lives in East Palo Alto and has a full house: her grown son, his three young daughters under four, and her daughter, plus her son's ex-partner, who lives in the garage and pays rent. Carter, a UPS driver, faced the threat of foreclosure on her three-bedroom ranch-style home, bought in 2003 for $447,000, but with help was able to save her home.

Michael Seibel, the CEO of Y Combinator, sees a roughly generational shift in Silicon Valley today. Younger workers want their companies to hire diverse employees and act with a bigger social conscience. Firms, desperate to hold on to talent, are falling in line.

And what about his purpose? After graduating from Yale University, Seibel planned to spend his 20s making money, his 30s being a parent, and his 40s going into politics. He moved to San Francisco in 2006 and started a company. He was co-founder and CEO of Justin.tv and Socialcam. Socialcam was sold to Autodesk in 2012, and Justin.tv eventually became Twitch Interactive. Now 36, he just became a father. But politics are out; he feels he has more social impact now.

If Silicon Valley has a spiritual center, it might be the Internet Archive, a nonprofit inside a former church in San Francisco. Servers churn away day and night, archiving much of the public web in its many forms. Nearly every Wikipedia article. About four million tweets a day. More than a half million YouTube videos a week. It's archived more than 340 billion web pages. The internet's lost and found.

Fog blowing in through open windows keeps the archive's servers from overheating.

Scattered among the pews in the archive's Great Room are more than 120 three-foot-high statues of people who have contributed at least three years to the archive. The internet's terra-cotta army. I recognize some of them in this eerie but powerful scene.

It's kind of creepy, these lifelike statues, some holding a book or a cup or a guitar, as if they were interrupted while working on a project or taking part in a sing-along. Or, perhaps, while arguing with each other about the right thing to do. □

Michelle Quinn is the Silicon Valley bureau chief for Voice of America and has covered the region since 1994. Photographer **Laura Morton** is based in San Francisco.

BY **JEREMY BERLIN**
PHOTOGRAPHS BY **STEFANO UNTERTHINER**



KANGAROOS ARE THE
HOPPING **ICONS OF AUSTRALIA.**
THEY ALSO **DESTROY CROPS**
AND **CAUSE CAR ACCIDENTS.**

NOW THE NATION IS DEBATING
WHAT TO DO WHEN A

BELOVED SYMBOL



BECOMES A PEST.

Eastern gray kangaroos forage on a lawn in North Durras, a village in New South Wales. Driven by droughts, groups of roos (called mobs) are increasingly coming into contact with humans.

PREVIOUS PHOTO

Red kangaroos thrive in arid grasslands like these in Sturt National Park. Australia is home to 25 million people and an estimated 50 million kangaroos, which some Aussies call "plague proportions."



A mother kangaroo and her joey hop across Main Street to graze on a scruff of grass growing near a gas pump.

It's a cool spring evening in White Cliffs, a quirky opal-mining town in New South Wales. Locals live like hobbits here, in ventilated holes. Thousands of mine shafts pock the parched earth. But the two eastern gray kangaroos are the oddest sight around.

"I've never seen them in town like this," says George Wilson, a professorial ecologist who's been studying kangaroos for five decades. "I wonder if they're someone's pets."

Tourists point and gawk. Children ooh and aah. When the sun begins to set, the "roos"—Aussie shorthand for the hopping animals—head out of town. A while later, a young man finishes his beer in the local saloon. He pays his bill, climbs into a white truck with hooks on the back, and drives off. His job that night: to kill as many kangaroos as he can.

Australia has a complicated relationship with its national symbol. Kangaroos are among the world's most iconic, charismatic species—the living, bounding emblems of the country's unique biodiversity. At once sublime and adorably absurd, they are evolutionary marvels—the only large animal that hops.

And Australians are demonstrably proud of them. Kangaroos star in movies and TV shows, poems and children's books. Their images adorn the country's currency, coat of arms, commercial airlines, naval vessels, Olympic insignia, and athletic uniforms. To outsiders, the big-footed, fat-tailed, perky-eared creatures are a stand-in for the country itself: Australia means roos, and roos mean Australia. There may be no animal and nation in the world more closely identified.

But there are more than twice as many kangaroos as people in Australia, according to official



Two young males duke it out near Grampians National Park in Victoria. The image of a "boxing" kangaroo—now a ubiquitous symbol of Australia—first appeared in an 1891 cartoon inspired by exhibitions that pitted man against roo.



government figures, and many Aussies consider them pests. Landholding farmers, called graziers, say that the country's estimated 50 million kangaroos damage their crops and compete with livestock for scarce resources.

Australia's insurance industry says that kangaroos are involved in more than 80 percent of the 20,000-plus vehicle-animal collisions reported each year. In the country's arid, sparsely populated interior, the common belief is that roo numbers have swollen to "plague proportions." In the absence of traditional predators such as dingoes and Aboriginal hunters, the thinking goes, killing kangaroos is crucial to balancing the ecology.

And to boosting the rural economy. A government-sanctioned industry, based on the commercial harvest of kangaroo meat and hides, exported $29 million in products in 2017 and supports about 4,000 jobs. Today meat, hides, and leather from four nonthreatened species—eastern grays, western grays, reds, and common wallaroos—have been exported to 56 countries. Global brands such as Nike, Puma, and Adidas buy strong, supple "k-leather" to make athletic gear. And kangaroo meat, once sold mainly as pet food, is finding its way into more and more grocery stores and high-end restaurants.

Four of Australia's eight states and territories manage annual quota-based culls that supply the industry. (Small-scale trial harvests are also under way in Victoria and Tasmania.) Advocates point out that low-fat, high-protein kangaroo meat comes from an animal more environmentally friendly than greenhouse gas–emitting sheep and cattle. John Kelly, former executive director of the Kangaroo Industry Association of Australia, says, "Harvesting our food and fibers from animals adapted to Australia's fragile rangelands is eminently wise and sustainable. Many ecologists will tell you that there is no more humane way of producing red meat."

Opponents of the industry are a vocal minority. Animal welfare organizations, celebrities, and a growing number of scientists call the culls inhumane, unsustainable, and

unnecessary. Population estimates are highly debatable, they say, but "plague proportions" are biologically implausible. Joeys grow slowly, and many die, so kangaroo populations can expand by only 10 to 15 percent a year, and then only under the best of circumstances.

Dwayne Bannon-Harrison, a member of the Yuin people of New South Wales, says the idea that kangaroos are destroying the country is laughable. "They've been walking this land a lot longer than people have," he says. "How could something that's been here for millennia be 'destroying' the country? I don't understand the logic in that."

In many ways, the controversy boils down to an existential question: What is a kangaroo? To some, it's a pest to be eradicated. To others, it's a resource to be exploited. Still others see a beloved native animal to be conserved. These conflicting views are pitting neighbor against neighbor, especially in rural areas. Australia, it seems, is a nation divided over a bounding marsupial.



"THAT'S KANGAROO COUNTRY DOWN THERE," says Wilson, the ecologist, pointing out the window of his Cessna at a patch of thick scrub 8,000 feet below. "Down there" are dusty rangelands and the sunburned outback, a fragile landscape where fertile soil can quickly turn to dust and water supply never meets demand. Farming has always been a challenge on Earth's second driest continent, and now climate change is exacerbating heat waves and droughts, intensifying pressure on agriculture and livelihoods.

Overgrazing is a constant worry, says grazier Leon Zanker. And kangaroos only make it worse. Sitting at his kitchen table in Laurelvale on an August afternoon, the burly farmer explains his plight. When there's a drought, he can manage feed, water, and livestock accordingly. But kangaroos on his land aren't his to manage—the government owns them.

"If I let my cattle and sheep die of starvation, I could end up in jail" for animal cruelty, Zanker says. "But I can see my country degraded by kangaroos, and I can do nothing about it myself."

He does have a few options. One is the commercial harvest. Graziers can allow licensed shooters to cull groups of kangaroos, called mobs, on their land. But as demand for kangaroo products has waned—in part because of publicity efforts by animal welfare organizations—the industry has been taking only a fraction of the annual cull allowed. In 2017 Australia's total quota was about 7.2 million, yet fewer than 1.5 million kangaroos were shot.

Another option is cluster fencing. Graziers with adjacent properties can band together and erect a government-subsidized fence around their farms. But critics say the barriers cruelly snare kangaroos, illegally hinder their access to water, and disrupt the migratory routes of other native animals.

The final option is simple execution. A grazier can apply for a permit that authorizes killing a specific number of animals. At the time of my visit, Zanker had one to cull 500 roos. But many graziers with permits hire amateur shooters with no training or accreditation, unlike the marksmen employed and monitored by the industry. That creates its own problems, including thousands of maimed roos each year.

"If you own a property," Zanker says, "you've probably got a mortgage. And the bank wants its money. But there's one animal you're not



At the Anglesea Golf Club in Victoria, a golfer and a mob of eastern grays enjoy the turf in different ways. Kangaroos are a common sight on Aussie courses—a draw for tourists and an opportunity for scientists to tag, track, and study the animals.

allowed to manage, and you're seeing your whole livelihood getting eaten out from under you. What would you do in that situation? Go and give the keys to the bank manager? Or go and buy a box of bullets?"

AS THE SUN GOES DOWN in rural Queensland, Brad Cooper goes to work. The stout kangaroo shooter pulls his truck off the road and into a paddock about 20 miles east of Mitchell. "We'll get as many as we can tonight," he says. "But I don't like this wind. And neither do they."

"They" are the eastern grays he's come here to kill. When wind gusts, mobs cluster warily, which makes it harder for shooters to pick off the adult males they're legally allowed to harvest. Commercial shooters have to pass a marksmanship test and receive training on animal welfare and hygiene. Each month they have to report the details of their work to ensure that no harvest exceeds the quota.

Cooper is 41 years old. He shot his first kangaroo when he was five. Today he works three nights a week, for six to eight hours at a time. His goal this evening is to kill 30 roos. His single-night record is 104.

As ragged clouds scuttle overhead, the half-moon plays peekaboo in the night sky. A sharp smell of saltbush fills the air. Cooper sweeps the lights on his truck back and forth, back and forth. A minute later he finds what he's after. An adult male stands 300 feet away, six feet tall, staring at the truck's lights as though hypnotized. Boom! The report from Cooper's rifle rends the night. The kangaroo crumples in a heap.

Cooper drives to the fallen roo. He yanks the carcass onto the truck bed and hangs it by a rear leg. Working with practiced efficiency, he bleeds the animal, then eviscerates it, inspecting the carcass for lesions or parasites that would compromise its market value. He hacks off the kangaroo's forepaws, decapitates it, and slices off its tail—a delicacy to Aboriginals that's left in the red dust.

Next comes paperwork: Every shooter must





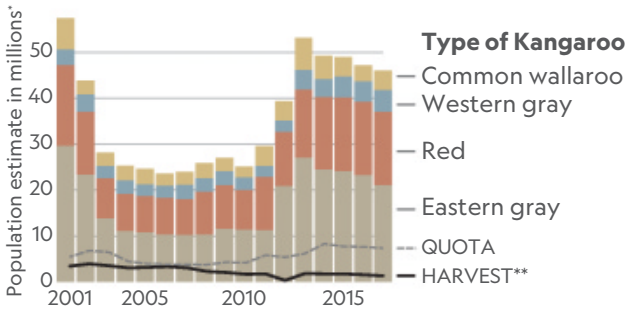
At Depot Beach in Murramarang National Park, a mob of eastern grays navigates the rocky shore. Kangaroos have adapted to nearly every habitat in Australia, says zoologist Tim Flannery, “from underground burrows to the treetops of tropical forests.”

Professional shooter Peter Absalom processes the male red kangaroos he culled near Mulyungarie Station in South Australia. To address the welfare of joeys orphaned when their mothers were shot, the industry moved to a male-only harvest in 2013.



Too many roos?

The kangaroo family includes more than 70 species, four of which are legally hunted in designated harvest areas. Advocates of commercial culling say it keeps roo numbers in check. Critics say hunting quotas are based on inflated population estimates.





Common wallaroo
Macropus robustus
Smaller than their kangaroo cousins, an estimated 4.3 million wallaroos range countrywide.





Western gray
Macropus fuliginosus
This southern species is called the western gray because it lives west of the Great Dividing Range.





Red
Macropus rufus
Australia's largest roo grows up to six feet tall and 200 pounds. Its estimated population tops 15.8 million.





Eastern gray
Macropus giganteus
This roo's range overlaps major cities, leading to conflict. Hunt quotas are high, but actual kills are far lower.





record the date and time of each kill, the name of the property, the species, and all the other information required by the food processor and the state authority. The red tape can be a pain, Cooper says, but it's worth it. He gets paid 70 cents per kilogram for field-dressed carcasses. Some nights he can make a thousand dollars.

When he's done, he climbs back into his truck and drives on. Two males appear. Boom! Boom! The process repeats. A little before midnight the wind kicks up in earnest, and Cooper calls it a night. His final tally: 10 kangaroos.

"There's nothing normal about this job," he says on the way back to Roma, where he'll deposit his haul in a "chiller box"—a refrigerated depot where carcasses are stored before they're processed. The hours are strange, the work brutal. Urbanites look down on his profession.

"To them, we're the lowest of the low," Cooper says. "But city people are cut off from the animals in their lives. If a dog or a cat needs to be put down, a vet does it. They're not directly responsible. But we are."

NGM MAPS. ART: TAYLOR MAGGIACOMO, NGM STAFF. SOURCES: AUSTRALIAN DEPARTMENT OF THE ENVIRONMENT AND ENERGY; DAVID CROSS, UNIVERSITY OF NEW SOUTH WALES SYDNEY

*POPULATION ESTIMATES COVER ONLY NEW SOUTH WALES, QUEENSLAND, SOUTH AUSTRALIA, AND WESTERN AUSTRALIA.
**2017 HARVEST FIGURES ARE INCOMPLETE, WITH NO DATA FOR WESTERN AUSTRALIA.



Garry McLean feeds orphaned kangaroos at Horizons Kangaroo Sanctuary in Agnes Water, Queensland. "They're family animals just like we are," says Nikki Sutterby of the Australian Society for Kangaroos. "They really suffer when they lose their joey—or when the joey loses its mum."

HOWARD RALPH, a tall, trim doctor, sits in his drafty waiting room and describes another kind of responsibility for kangaroos. Ralph and his wife, Glenda, turned their land in Braidwood, an hour's drive from Canberra, into a wildlife sanctuary 18 years ago. Today, aided by a small army of volunteers, Southern Cross Wildlife Care treats more than 2,000 animals a year. Over half are kangaroos.

"Our main objective in life is animal welfare," Ralph says. "We try to help these critters and get them to a state where they can be released back into the wild. We don't discriminate among species. And we don't give up easily."

That means treating pain and managing stress, which can be fatal issues. Kangaroos, especially eastern grays, get stressed easily and can develop kidney failure and heart disease. "We see it all the time," Ralph says.

They also see a lot of cruelty: kangaroos that have been shot in the face, hit with an ax, deliberately run over by a truck. Some can't hop because of compound fractures to their legs.

"In this so-called civilized country," Ralph says, "things are done that shouldn't be done. Sadly, a lot of it goes on not because there's some population explosion. It happens because people think it's funny or enjoyable to torment little creatures. We should be beyond the point where cruelty is acceptable. Under any circumstances."

Across Australia, dozens of roo refuges have popped up in recent years. Like Southern Cross, most are charities in the purest sense: Virtually every cent goes toward medicine and utilities.

Ralph says he's realistic about people's views toward kangaroos, but hopeful that things may be getting better. "I think the general population is gradually changing," he says. "Twenty years ago, few people thought these critters deserved to be respected. But there's a growing awareness that they suffer pain. And we need to understand that and treat them accordingly."

Ray Mjadwesch agrees. A hundred sixty miles to the north, in the Capertee Valley, the scruffy freelance ecologist is standing in a thickly wooded plot, feeding a scrum of kangaroos on a





Tourists of all ages gawk at eastern gray kangaroos on Cape Hillsborough beach in Mackay, Queensland. The site has become a popular tourist attraction and a boon for the local economy. Australia is the only place in the world to see kangaroos in the wild.

nippy spring night. Twenty juveniles are jostling for the horse feed in his open hand.

"Come on, guys!" says Mjadwesch. "No fighting. You're all herbivores."

Six weeks earlier these roos lived 50 miles away, in Bathurst. That's where Mjadwesch lives too, with his wife, Helen Bergen. Two years ago the couple led a massive volunteer effort to relocate hundreds of kangaroos from Mount Panorama, the site of a major international racetrack. Officials there wanted to kill the animals, but after years of bitter wrangling, Mjadwesch and Bergen gained permission to relocate them.

Time will tell if it worked. The translocation may have disrupted family groups, and it's unclear whether the roos will stay in their new home. Some have already dispersed, causing residents to complain about the new neighbors.

Mjadwesch, a critic of the kangaroo industry, says the methodology for counting the animals is flawed. Annual surveys include areas where kangaroos abound. But Mjadwesch says those numbers are extrapolated to places with few if any roos, resulting in inflated population estimates—a claim the industry disputes. "We have all these studies saying there are twice as many kangaroos as humans," he says. "But look around—they've disappeared from the landscape. People only notice where they are. They don't notice where they're not."

Over the past 200 years, he says, "kangaroo management has meant kangaroo shooting. We need a reset on that philosophy."



CAN AUSTRALIANS' CONFLICTING attitudes toward kangaroos be reconciled? George Wilson says that if roos were privately owned, then graziers—working independently or through wildlife conservancies—would protect the animals, treating them as assets. They could feed them, lease them, breed them, and charge hunters a fee for access. They just need an incentive to do so.

"If you want to conserve something," Wilson says, "you have to give it a value. Animals that are considered pests don't have value."

Privatization could also help reduce grazing pressures. If kangaroos were more valuable than cattle or sheep, farmers would keep less livestock, which could be good for the environment. Under this scenario, landholders would work with the kangaroo industry on branding, marketing, and quality control. The government's role would be oversight and regulation.

Leon Zanker is all for it. "For us, the best outcome is to have a well-managed commercial industry that can keep kangaroo numbers in line with pasture and water conditions. But you've got to have the management tools, the ability, to keep things in balance. That's what landowners right now are screaming out for."

ON A BALMY SEPTEMBER afternoon in Woronora, half an hour from Sydney, 82-year-old Yuin elder Uncle Max "Dulumunmun" Harrison is explaining the complex relationship that indigenous Australians have with kangaroos—a cultural, social, and spiritual connection that stretches back at least 50,000 years.

Native Australians have always eaten kangaroos, but they've done so according to strict protocols. Uncle Max says indigenous law permits hunting, but only seasonally and not during times of breeding. Nor should anything be wasted. Every part of a kangaroo should be used: meat for eating and sharing; sinew for making thread; skin for warm, waterproof garments,



A western gray and the photographer's son take stock of each other at a homestead in Sturt National Park. Few animals capture the imagination as roos do. "So breathtakingly different is the kangaroo," writes zoologist Flannery, "that if it did not exist, we'd be unable to imagine it."

sewn with needles made from the bones; fur for bags and clothing.

But the relationship is about more than utility. Kangaroos are central players in the rich symbolic world Aboriginals call the Dreamtime—stories that explain life and creation. Songlines are part of this—paths across the outback that mark the routes traveled by ancestors. Uncle Max says kangaroo culls are damaging these tracks.

Despite their long association with kangaroos, indigenous Australians have little say in how their country treats its national symbol. While there may be no single indigenous stance—groups are too geographically and culturally diverse—most agree that culling is a big concern.

Sitting in his office at Macquarie University in Sydney, a hefty Gomeroi elder named Phil Duncan says Australia is an odd place: "The only country that eats its coat of arms."

Like Uncle Max, he's aghast at how kangaroos are treated. "Culling," he says, "is getting in the way of our ability to teach our next generations about the connection to our country—to our totemic species." His solution is simple: Let Australia's first people have the last word on kangaroo management. After all, they did just fine for thousands of years. "If you're going to cull kangaroos," says Duncan, "then there should be an industry. But that industry should be monopolized by Aboriginal people. We'd do it humanely. Give us the licenses. Let us do this."

Of course, getting there "would take a huge generational shift in ideologies. It would require a lot of champions within the parliamentary systems. But it could be done."

In the meantime, Duncan has a more immediate message. "When tourists come to Australia, they want to hug a kangaroo, hold a koala bear, meet an Aboriginal person. All three are interconnected in our lore. Understand that connection. Don't come out here to kill. Come out here to embrace." □

Jeremy Berlin wrote about Italy's Gran Paradiso National Park for the February 2015 issue. Photographer and zoologist **Stefano Unterthiner** specializes in telling the life stories of animals.



YOUR SHOT

ALVIS LAZARUS

PHOTOS FROM OUR COMMUNITY

WHO

Alvis Lazarus, 37, a supply-chain and management consultant in Bangalore, India

WHERE

Bandipur National Park in India's Karnataka state

WHAT

A Nikon D810 camera with a 150-600mm lens

During an early morning safari through Bandipur National Park, an area known for its wildlife, Lazarus and several friends spent hours tracking a tiger. They stopped at one clearing and noticed about 10 deer. Lazarus's friends wanted to move on, but he asked them to wait. Two deer stood before a verdant background, first one and then the other turning to look at the group of tourists. "I wished both would look at me, and I imagined that frame in my mind," he says. Then both deer did, and he got the shot.

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Eastern Quoll *(Dasyurus viverrinus)*

Size: Body length, 48 - 58 cm (18.9 - 22.8 inches); tail, 17 - 28 cm (6.7 - 11 inches) **Weight:** Males approx. 1.1 kg (2.4 lbs); females approx. 0.7 kg (1.5 lbs) **Habitat:** Primarily grasslands, dry eucalyptus forests, scrublands and heathlands **Surviving number:** Estimated at 10,000 - 12,000

Photographed by Martin Willis

WILDLIFE AS CANON SEES IT

Head first. When the eastern quoll engages prey, it goes straight for the head and bites. Insects and agricultural pests are favored targets, but the opportunistic eater is also able to sniff out and dig up food buried underground. This ability turns into a liability, however, when it encounters poisoned baits. Having disappeared from mainland Australia in the 1960s, this marsupial is headed into the danger zone in its last strongholds due to fluctuations in weather, roadkill mortality and predation by feral cats.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.



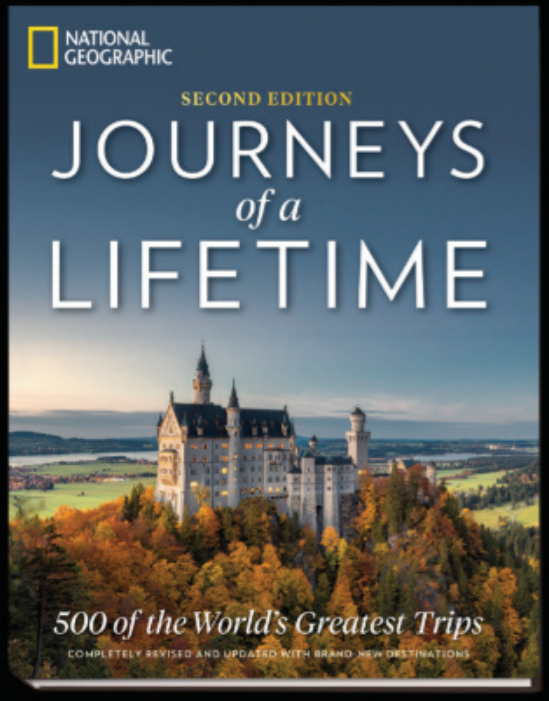
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